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MAY 20 2003

Subject: SECTION C.2.6, REMEDIATE SITE GROUNDWATER AND SECTION H.4, TRI-PARTY AGREEMENT OF THE PHMC; TRANSMITTAL OF THE *CALENDAR YEAR 2002 ANNUAL SUMMARY REPORT FOR THE 100-HR-3, 100-KR-4, AND 100-NR-2 OPERABLE UNIT PUMP-AND-TREAT OPERATIONS,* DOE/RL-2003-09, REVISION 0

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Mr. Keith A. Klein, Manager
U.S. Department of Energy
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Post Office Box 550
Richland, Washington 99352

Dear Mr. Klein:

SECTION C.2.6, REMEDIATE SITE GROUNDWATER AND SECTION H.4, TRI-PARTY AGREEMENT OF THE PHMC; TRANSMITTAL OF THE *CALENDAR YEAR 2002 ANNUAL SUMMARY REPORT FOR THE 100-HR-3, 100-KR-4, AND 100-NR-2 OPERABLE UNIT PUMP-AND-TREAT OPERATIONS,* DOE/RL-2003-09, REVISION 0

In accordance with Section C.2.6 and Section H.4 of the PHMC, this correspondence transmits the final version of the *Calendar Year 2002 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Unit Pump-and-Treat Operations*, DOE/RL-2003-09, Revision 0, for your use. This information has been reviewed by and coordinated with Ms. Arlene Tortoso and Mr. Mike Thompson.

If you have any technical questions, please contact Mr. Dick Wilde on 372-8123; contractual questions should be referred to Ms. Lori Hunter on 376-6986.

Very truly yours,

WJ Hoogendoorn for
David B. Van Leuven
President and
Chief Executive Officer

mrs

Attachment

RL- J. G. Morse
G. H. Sanders
M. H. Schlender

S. A. Sieracki (w/o attachment)
K. M. Thompson
A. C. Tortoso

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Calendar Year 2002 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Unit Pump-and-Treat Operations, DOE/RL-2003-09, Revision 0

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DOE/RL-2003-09
Revision 0

Calendar Year 2002 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Unit Pump-and-Treat Operations

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

**United States
Department of Energy**
**P.O. Box 550
Richland, Washington 99352**

Project Hanford Management Contractor for the
U.S. Department of Energy under Contract DE-AC06-96RL13200

DOE/RL-2003-09
Revision 0

Calendar Year 2002 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Unit Pump-and-Treat Operations

G. G. Kelty
R. F. Raidl
Fluor Hanford, Inc.

May 2003

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

United States Department of Energy
P.O. Box 550
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Project Hanford Management Contractor for the
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TERMS

CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
COC	contaminants of concern
CY	calendar year
EPA	U.S. Environmental Protection Agency
FY	fiscal year
HEIS	Hanford Environmental Information System
ISRM	in situ redox manipulation
ITRD	Innovative Treatment and Remediation Demonstration
LWDF	Liquid Waste Disposal Facility
LWDS	Liquid Waste Disposal Site
MCL	maximum contaminant level
NAVD88	North American Vertical Datum of 1988
N/A	not available
OU	operable unit
RAO	remedial action objective
ROD	Record of Decision
RPD	relative percent difference
RUM	Ringold Upper Mud
QC	quality control
TPH	total petroleum hydrocarbon
WIDS	Waste Information Data System

1.0 INTRODUCTION

Fluor Hanford is currently operating five groundwater pump-and-treat systems across the Hanford Site. Three systems address groundwater in the 100-Areas: the 100-HR-3 system treating hexavalent chromium at two sites (100-D and 100-H), the 100-KR-4 system also treating hexavalent chromium, and the 100-NR-2 system treating strontium-90. Two pump-and-treat systems are remediating groundwater in the 200 West Area: the 200-UP-1 system treating technetium-99, uranium, carbon tetrachloride, and nitrate; and the 200-ZP-1 system treating carbon tetrachloride, chloroform, and trichloroethene.

This annual summary report of progress and performance evaluation discusses the groundwater remedial actions in the 100 Areas, including the interim remedial actions at the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Units (OU) (Figure 1-1).

The interim remedial actions chosen for the 100-HR-3 and 100-KR-4 OUs are pump-and-treat systems that use an ion-exchange medium for contaminant removal. The systems were designed to achieve three remedial action objectives (RAO), as well as specific operational and aquifer performance criteria described in the interim remedial action Record of Decision (ROD) (EPA 1996, *Record of Decision for the 100-HR-3 and 100-KR-4 Operable Units at the Hanford Site Interim Remedial Actions*). The three remedial action objectives are identified as follows:

- RAO #1: Protect aquatic receptors in the river bottom substrate from contaminants in groundwater entering the Columbia River.
- RAO #2: Protect human health by preventing exposure to contaminants in the groundwater.
- RAO #3: Provide information that will lead to a final remedy.

The interim remedial action ROD for the 100-NR-1 and 100-NR-2 OUs specifies the selected remedy and activities for the 100-NR-2 OU (EPA, Ecology, and DOE 1999, *Interim Remedial Action Record of Decision for the 100-NR-1 and 100-NR-2 Operable Units, Hanford Site, Benton County, Washington*). Some of these remedial activities are ongoing actions, such as the pump-and-treat operation specified by the 1994 N-Springs Action Memorandum (Ecology and EPA 1994, "Action Memorandum: N-Springs Expedited Response Action Cleanup Plan, U.S. Department of Energy Hanford Site, Richland, Washington"). The 100-NR-2 RAOs are as follows:

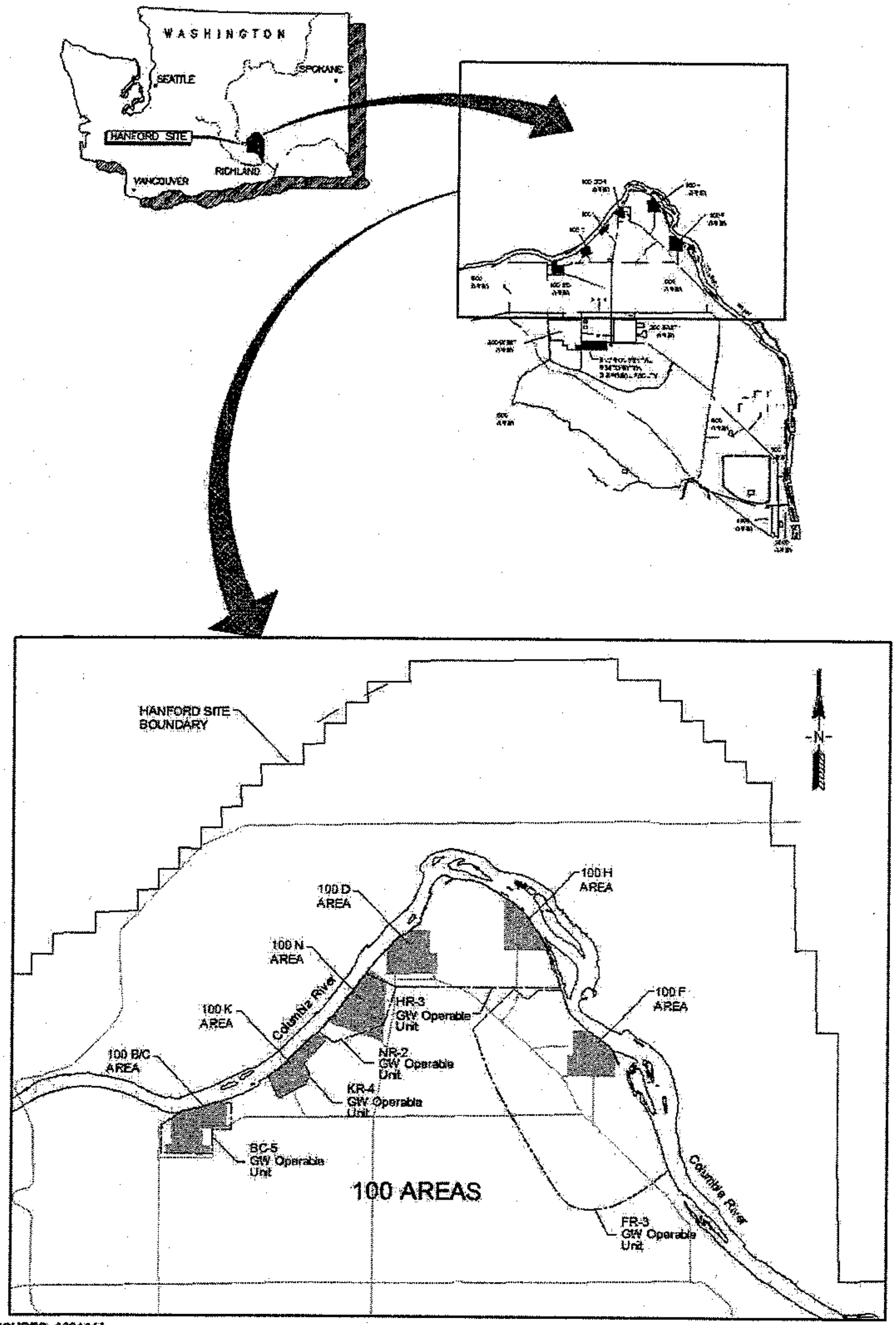
- RAO #1: Reduce strontium-90 contaminant flux from the groundwater to the Columbia River.
- RAO #2: Evaluate commercially available treatment options for strontium-90.
- RAO #3: Provide data necessary to set demonstrable strontium-90 cleanup standards.

This report discusses progress toward the RAOs for each OU in the appropriate conclusions section.

The report is organized into three major sections, each presenting the annual summary and performance evaluation for the three respective OUs. Section 2.0 discusses the 100-HR-3 OU, Section 3.0 discusses the 100-KR-4 OU, and Section 4.0 discusses the 100-NR-2 OU. An evaluation of costs is presented in Section 5.0.

This report provides a summary of major calendar year (CY) 2002 activities, major trends, and significant differences between 2001 and 2002 for each OU in the main body of the report. An updated conceptual model discussion also has been included for each OU. Additional detailed text, tables, and/or figures to provide historical information and trends are found in Appendices A through L.

Figure 1-1. 100 Area Groundwater Operable Units.



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2.0 100-HR-3 PUMP-AND-TREAT SYSTEM

The 100-HR-3 pump-and-treat facility is located in the north-central part of the Hanford Site along the Columbia River. The 100-HR-3 OU represents the groundwater underlying the source OUs that are associated with the 100-D and 100-H Reactor areas and the adjacent 600 Area (Figure 2-1). Groundwater extraction systems have been installed at the 100-D and 100-H Reactor areas, with a common treatment facility in a surplus building located near the H Reactor. The well locations for the 100-D Area are shown in Figure 2-2, and the 100-H Area well locations are shown in Figure 2-3. Treated groundwater is returned to the aquifer via injection wells, which are located in the 100-H Area, upgradient of the extraction well field. Appendix A provides a history of operations in the development of the HR-3 pump-and-treat system.

This section provides the CY 2002 annual summary report for pump-and-treat operations in the 100-HR-3 OU as required by DOE/RL-96-84, *Remedial Design Report and Remedial Action Work Plan for the 100-HR-3 and 100-KR-4 Groundwater Operable Units Interim Action.* Section 2.1 briefly discusses relevant concurrent activities within the OU and summarizes major operational changes. Section 2.2 summarizes the treatment system performance. Sections 2.3 and 2.4 review hydraulic conditions, provide a capture zone analysis through numerical modeling, and evaluate contaminant concentrations for the 100-D and 100-H Areas. Section 2.5 discusses quality control (QC) results for groundwater samples. Section 2.6 updates key information related to the site conceptual models. Sections 2.7 and 2.8 provide conclusions and recommendations for the pump-and-treat systems. Cost information is presented separately in Section 5.0.

2.1 CONCURRENT ACTIVITIES

Relevant activities that were completed in CY 2002 for the 100-HR-3 OU include the following:

- Some aquifer tube sampling was conducted in the fall of 2002 and winter of 2003 along the Columbia River low-water shoreline of the 100-D and 100-H Areas. Data will be reported in the CY 2003 semi-annual technical memorandum for 100-HR-3, 100-KR-4, and 100-NR-2.

- Phase III activities of the in situ redox manipulation (ISRM) technology were implemented to expand the remediation of the hexavalent chromium plume at the 100-D Area farther to the west. A total of 20 wells were installed: 17 treatment zone wells and 3 small-diameter monitoring wells. Twenty-three wells were treated with chemicals to extend or reestablish the treatment zone. Seventeen wells were treated to extend the existing treatment zone to the west, while six ISRM wells were treated with chemicals a second time to reestablish the treatment zone. In addition, the extraction process for nine wells treated in fiscal year (FY) 2001 was completed in FY 2002. A detailed description of the progress and performance of the ISRM technology is presented in DOE/RL-2003-05, *Fiscal Year 2002 Annual Summary Report for In-Situ REDOX Manipulation Operations.*

- Two additional extraction wells, 199-D8-68 and 199-D8-72, were incorporated into the pump-and-treat network to enhance the capture of a developing southern portion of the plume.

2.2 100-HR-3 TREATMENT SYSTEM PERFORMANCE

This section describes the 100-HR-3 pump-and-treat system operation and sampling activities. Information presented includes system availability, changes to the system configuration, mass of contaminants removed during operations, contaminant removal efficiencies, quantity and quality of extracted and disposed groundwater, waste generation, and short-term contaminant comparisons. Additional operational details are found in the associated section appendices.

System Modification/Operation

As a result of the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) 5-year review, extraction wells 199-D8-68 and 199-D8-72 were added in the 100-D Area to improve capture and containment of the contaminant plume in May 2002 (Figure 2-2). A third transfer pump was added at the 100-D Transfer Pump Building and a third booster pump was added at the 100-HR-3 Treatment Process Building. These new pumps provide redundancy and increased system availability. Figure 2-4 provides a system schematic, detailing the current configuration.

A summary of operational parameters and total system performance for CY 2002 is presented below:

100-HR-3 total processed groundwater: (million liters)		
	CY 2002	Since Startup 1997
100-D Area	166.4	797.7
100-H Area	184.1	734.1
Total	**350.5**	**1,531.8**
100-HR-3 total mass of hexavalent chromium removed: (kg)		
	CY 2002	Since Startup 1997
100-D Area	28.72	130.6
100-H Area	3.3	30.4
Total	**32.02**	**161**

Summary of 2002 operational parameters:	
Removal efficiency (% by mass)	93.8
Waste generation (m^3)	66.7
Low-level radioactive waste generation (m^3)	13.4
Regenerated resin installed (m^3)	32.2
New resin installed (m^3)	34.5
Number of resin changeouts	29
Summary of 2002 system availability:	
Total time on line (hours)	8,525
Total possible run time (hours)	8,760
Scheduled down time (hours)	218
Unscheduled down time (hours)	17
On-line availability (%)	97
Total system availability (%)	99.8

- The average removal efficiency ((influent–effluent)/influent) for CY 2002 exceeded 93.8 percent; this is higher than the 92 percent reported in CY 2001 (Figure 2-5).
- The 100-D Area influent hexavalent chromium concentration average of 160 µg/L in CY 2002 was lower than the CY 2001 average of 227 µg/L.
- The average CY 2002 hexavalent chromium concentration of 25.5 µg/L for the 100-H Area influent was lower than the 54 µg/L reported in CY 2001. Trend plots of CY 2002 influent and effluent concentrations are presented in Figure 2-6.
- Effluent concentrations were consistently below the maximum allowable concentration of 50 µg/L for the entire CY 2002 reporting period.
- Total system availability for CY 2002 was 99.8 percent (time on-line/total hours during the year minus scheduled outages), which was higher than the 97 percent reported in CY 2001. The on-line availability was 97 percent (time on-line/total hours during the year). This is a slight decrease from the on-line availability reported for CY 2001 (97.3 percent). System availability for CY 2002 is detailed in Figure 2-7.
- The return of river levels to nearly historic average levels increased the thickness of the aquifer. This increase in the available water and the addition of the two new extraction wells, 199-D8-68 and 199-D8-72, resulted in an increase in the productivity of the extraction wells (i.e., the rate at which the wells could be pumped) and the total amount of water pumped (by more wells).

During CY 2002, 29 spent ion-exchange vessels were changed out. The resin changeouts were performed based on a maximum operating time or percent chrome concentration, whichever limit was obtained first. The purpose of the limits was to reduce the amount of resin requiring regeneration by maximizing its operational life, while limiting the possibility of saturating the resin and creating a low-level radioactive waste that could not be shipped offsite for reprocessing. For all trains there is an 80 percent chrome concentration ratio of the lead vessel to influent concentrations. The time limits are area-dependent because of the different chemical/radiological characteristics of raw groundwater at each well. For the 100-D and 100-H Areas, the time limits were 120 and 90 days, respectively. Time limits were not implemented until late CY 2002. Nineteen vessels were changed out for the 100-D Area groundwater trains, averaging 124 days operation per vessel. Ten vessels were changed out for the 100-H Area groundwater treatment train, averaging 131 days of operation per vessel. During CY 2002, the vessels that were changed out equate to 66.7 m^3 of spent resin.

Historical presentation of operational parameters, total system performance, and extraction well chromium concentration and extraction rates can be found in Appendix B.

2.3 AQUIFER RESPONSE IN THE 100-D AREA

This section describes general hydrogeologic conditions in the 100-D Area, the numerical modeling conducted to evaluate the extraction well network, and the changes in contaminant concentrations in monitoring wells.

2.3.1 Hydrogeologic Conditions

The groundwater flow direction throughout the year was generally north/northwest (toward the Columbia River), except from May through August when the river stage is higher and the flow may be reversed or parallel the river. The average river stage elevation during November 2002 was 115.354 m compared to the average 1991-2002 November river stage elevations of 115.067 m. The maximum November 2002 hydraulic gradient was 0.002 toward the northwest. The estimated flow velocity ranged from 0.4 m/day to 4 m/day based on a November 2002 gradient of 0.002, a hydraulic conductivity of 30 m/day to 300 m/day, and a 15 percent porosity. Additional information summarizing the hydrogeologic conditions and aquifer response in the 100-D Area is presented in Appendix C.

2.3.2 Numerical Modeling and Field Validation of Zone of Influence

Numerical modeling results indicate that contaminated groundwater was contained and prevented from discharging into the Columbia River in the northern part of the 100-D Area. The addition of extraction well 199-D8-72 and the conversion of compliance well 199-D8-68 to an extraction well have extended the hydraulic capture zone to the west (Figures 2-8 and 2-9). The pump-and-treat system is containing the plume from the reactors north to the river on which the original extraction well network was based.

Water-level measurements collected at 100-D Area monitoring wells were used to establish the zone of influence of the extraction wells. Five monitoring wells are equipped with pressure transducers and data loggers to measure water-level changes in the vicinity of the extraction wells. The maximum calculated drawdown was 0.08 m in well 199-D8-71, located between extraction wells 199-D8-53 and 199-D8-54A. These field data confirm the modeling conclusion of plume containment. A complete listing of drawdown calculated from water-level data and estimated drawdown from the model for specific wells is found in Table 2-1.

A more detailed discussion of model development is found in Appendix D.

2.3.3 Contaminant Monitoring in the 100-D Area

This section summarizes and interprets the analytical results obtained from groundwater wells included in the interim remedial action and OU monitoring programs in the 100-D Area. Data are stored in the Hanford Environmental Information System (HEIS) database or in the Project Specific Database.

The principal contaminant of concern (COC) in the 100-D Area is hexavalent chromium. The RAO for reduction of chromium concentration is 22 µg/L. Co-contaminants are strontium-90 and tritium; nitrate and sulfate are contaminants of interest. Section 2.3.3.1 discusses the results of chromium monitoring, and Section 2.3.3.2 discusses the results of co-contaminant monitoring. Locations of the monitoring wells and aquifer sampling tubes are shown in Figure 2-2.

CY 2002 Highlights:

- Fall 2002 chromium concentrations decreased in extraction wells and compliance wells when compared to fall 2001, but were not below the RAO.
- Chromium concentrations up to 627 µg/L have been detected in well 199-D5-20. This represents an increase by a factor of about 3 from last year. This well is located within 150 m of the Columbia River and outside the extraction well capture zone.
- Strontium-90 and tritium concentrations were less than the maximum contaminant levels (MCL) in all 100-D Area samples collected during CY 2002.

2.3.3.1 100-D Area Chromium Monitoring Results. Chromium concentrations are monitored in four 100-D Area pump-and-treat extraction wells, two compliance wells, and twenty monitoring wells. As shown below, chromium decreased from CY 2001 to CY 2002 in three of four extraction wells and the two compliance wells.

Well Name	Type	Fall 2001 (Cr, µg/L)	Fall 2002 (Cr, µg/L)	Percent Change
199-D8-53	Extraction	232	146	-37
199-D8-54A	Extraction	248	140	-44
199-D8-68	Extraction (after 5/2/2002)	280	106	-62
199-D8-69	Compliance	142	81	-42
199-D8-70	Compliance	197	150	-24
199-D8-72	Extraction	N/A	537	--

N/A = not available.

Extraction well 199-D8-72 came on line in May 2002, and therefore no annual comparison could be made.

Chromium concentrations increased significantly northwest of the 100-D Reactor and north of the 182-D Reservoir. It is possible that these chromium increases originate from an unlocated source between the sodium dichromate transfer station and the 100-D Reactor, or simply movement of the existing plume. Chromium data are presented below from wells in which chromium increased significantly.

Well Name	Type	Fall 2001 (Cr, µg/L)	Fall 2002 (Cr, µg/L)	Percent Change
199-D5-20	Monitoring	180	627	+248
199-D5-41	Monitoring	48.8	489	+902
199-D5-15	Monitoring	15.3	302	+1874
199-D5-42	Monitoring	13.1	33.8	+158

NOTE: Chromium and other co-contaminant concentrations in well 199-D5-15 have fluctuated widely over the years.

Figure 2-10 displays the fall 2002 100-D Area chromium plume and associated historical trends. Most data were collected in October and November 2002. The values displayed are filtered total chromium and hexavalent chromium concentrations.

2.3.3.2 100-D Area Co-Contaminant Monitoring Results. The 100-D Area co-contaminants are strontium-90 and tritium (DOE/RL-96-90, *Interim Action Monitoring Plan for the 100-HR-3 and 100-KR-4 Operable Units*). Other constituents of concern include nitrate and sulfate.

Strontium-90 and tritium concentrations were measured in samples from two compliance wells, four extraction wells, and four monitoring wells. No samples collected during 2002 contained strontium-90 above the 8 pCi/L MCL or tritium above the 20,000 pCi/L MCL. The maximum strontium-90 concentration detected was 7.06 ($\pm$1.07) pCi/L in well 199-D8-68; the maximum tritium concentration detected was 14,600 ($\pm$710) pCi/L in well 199-D5-17.

Nitrate was detected above the 45 mg/L MCL in 7 of 16 wells during 2002. The maximum concentration was 89.9 mg/L in well 199-D5-13. The high concentration area of the nitrate plume is located around the 100-D and 100-DR Reactors and west of the 182-D Reservoir.

Sulfate was not detected above the 250 mg/L secondary MCL in any of the 15 wells sampled during 2002. The maximum concentration detected was 156 mg/L in well 199-D5-16, east of the 100-D Reactor.

Appendix E presents a historical summary of contaminant and co-contaminant monitoring results.

2.4 AQUIFER RESPONSE IN THE 100-H AREA

This section describes the general hydrologic conditions in the 100-H Area, the numerical modeling conducted to evaluate the extraction well network, and the changes in contaminant concentrations in monitoring wells.

2.4.1 Hydrogeologic Conditions in the 100-H Area

The groundwater flow direction was generally northeast, or toward the river, except from May through August when river stage is higher and the flow direction is reversed. The average river stage elevation during November 2002 was 115.354 m compared to the lower average 1991-2002 November river stage elevation of 115.067 m. The maximum November 2002 hydraulic gradient was 0.002 toward the northeast. The estimated flow velocity was 0.3 m/day based on a November 2002 gradient of 0.002, an average hydraulic conductivity of 30 m/day, and 20 percent porosity. Additional information summarizing the hydrogeologic condition and aquifer response in the 100-H Area is presented in Appendix C.

2.4.2 Numerical Modeling and Field Validation of Zone of Influence

Numerical modeling results indicate that much of the contaminated groundwater was hydraulically contained and prevented from discharging into the Columbia River along the 100-H Area shoreline (Figure 2-11). Gaps in hydraulic capture largely are due to insufficient saturated Hanford formation thickness in the area of well 199-H4-65 to allow continuous operation. The most significant modeled gap in capture is between wells 199-H4-12A and 199-H4-11. This gap was not present when 199-H4-65 was operating.

Water-level measurements in 100-H Area monitoring wells were used to establish the zone of influence of the extraction wells. Thirteen monitoring wells are equipped with pressure transducers and data loggers. Nine of the equipped wells monitor water levels near the extraction wells, and two equipped wells are near the injection wells. The maximum drawdown in a well not along the Columbia River shoreline was 0.07 m in well 199-H4-5 (Table 2-1).

Well 199-H4-65 (acting as a monitoring well) was characterized by a drawdown of 0.03 m, indicating that the well is within the zone of influence of the adjacent extraction wells. However, as shown on Figure 2-12, water flowing through well 199-H4-65 continues to the river because hydraulic control caused by the Columbia River is more significant than that produced by extraction wells 199-H4-11 and 199-H4-12A.

A general discussion of model development is found in Appendix D.

2.4.3 Contaminant Monitoring in the 100-H Area

This section summarizes and interprets analytical results obtained from groundwater monitoring wells and aquifer sampling tubes supporting the 100-H Area pump-and-treat remedial action and the 100-HR-3 OU monitoring program. Section 2.4.3.1 includes a discussion about chromium monitoring results. The RAO for reduction of chromium concentrations is 22 µg/L. Section 2.4.3.2 includes a discussion about monitoring results for remedial action co-contaminants strontium-90, tritium, nitrate, technetium-99, and uranium.

<u>CY 2002 Highlights</u>:

- The highest chromium concentrations were downgradient of the former 183-H Solar Evaporation Basins, near extraction well 199-H4-12A, which had concentrations up to 50 µg/L.
- The maximum November 2002 compliance well chromium concentration was 65 µg/L in 199-H4-4. Other compliance well concentrations ranged from 20 to 50 µg/L chromium.
- The November 2002 chromium concentration in extraction well 199-H3-2A was 16 µg/L. Concentrations in this well were more than 100 µg/L in 1997 when pump-and-treat operations began, but annual November values have been below the RAO for the past 4 years.
- November 2002 chromium concentrations in the other 100-H Area extraction wells ranged from 31 µg/L in 199-H4-11 to 50 µg/L in 199-H4-12A, which are above the RAO.

Chromium and co-contaminant concentrations increased in wells downgradient of the former 183-H Solar Evaporation Basins. These increases may have been the result of mobilizing vadose zone contaminants with dust suppression water used during CY 2002 excavation of a former septic field upgradient of the former 183-H facility.

2.4.3.1 100-H Area Chromium Monitoring Results. Chromium is monitored in the 100-H Area in 5 extraction wells, 4 compliance wells, and 19 monitoring wells (Figure 2-3). Figure 2-13 illustrates the fall 2002 100-H chromium plume and associated historical chromium trends.

As shown below, fall 2002 chromium concentrations varied in extraction wells when compared to fall 2001. Chromium concentrations decreased significantly in three of four compliance wells. The increase in well 199-H4-4 may be a result of the gap in hydraulic capture caused by the shutdown of extraction well 199-H4-65. It should be noted that well 199-H4-4 has displayed variation in concentration over the years.

Well Name	Type	Fall 2001 (Cr, µg/L)	Fall 2002[a] (Cr, µg/L)	Percent Change[b]
199-H3-2A	Extraction	13.1	16	+22.1
199-H4-7	Extraction	16.9	44	+160

Well Name	Type	Fall 2001 (Cr, µg/L)	Fall 2002[a] (Cr, µg/L)	Percent Change[b]
199-H4-11	Extraction	41	31	-24.4
199-H4-12A	Extraction	47.1	50	+6.2
199-H4-15A	Extraction	53	46	-13.2
199-H4-4	Compliance	45.3	65	+43.5
199-H4-5	Compliance	60	48	-20
199-H4-63	Compliance	76	23	-69.7
199-H4-64	Compliance	81.6	45	-44.8
199-H4-3	Monitoring	35.7	78	+118
199-H4-8	Monitoring	18	38	+111
199-H4-9	Monitoring	27	51	+89

[a]Remedial action objective is 22 µg/L.
[b](2001-2002)/2001.

Chromium concentrations increased significantly in wells 199-H4-3, 199-H4-8, and 199-H4-9. The cause of these increases is uncertain, but may be related to dust suppression water applied to remediation of a septic field east of the former 183-H Solar Evaporation Basins.

The most prominent decreases in chromium concentrations were found in extraction, compliance, and monitoring wells upgradient and downgradient of the former 107-H Retention Basin in the southern part of the 100-H Area. This area probably has been most impacted by plume dilution from the 100-HR-3 pump-and-treat injection wells and these results are summarized below.

Well Name	Type	Fall 2001 (Cr, µg/L)	Fall 2002[a] (Cr, µg/L)	Percent Change[b]
199-H4-18	Monitoring	39.6	27	-31.8
199-H4-14	Monitoring	45.8	32	-30.1

[a]Remedial action objective is 22 µg/L.
[b](Fall 2001-fall 2002)/fall 2001.

Figure 2-13 displays the fall 2002 100-H chromium plume and associated historical trends. Most data were collected in October and November 2002. The values displayed are filtered total chromium and hexavalent chromium concentrations.

2.4.3.2 100-H Area Co-Contaminant Monitoring Results. The 100-H Area co-contaminants are strontium-90, technetium-99, uranium, tritium, and nitrate (DOE/RL-96-90).

<u>Strontium-90</u>. Five of 15 well samples analyzed for strontium-90 in November 2002 were above the 8 pCi/L MCL, similar to 2001. Four of the five wells above the strontium-90 MCL are located downgradient of the former 107-H Retention Basin or the former 116-H-1 Liquid Waste Disposal Trench. Both of these facilities were excavated in 1999-2000 and backfilled in 2001. Strontium-90 concentrations, although above the MCL, were stable or decreasing, comparing

November 2001 to November 2002 results (presented below). "Stable" is defined as any 2002 result that is within 20 percent of the 2001 result.

Well Name	Type	Nov 2001 (Sr-90, pCi/L)	Nov 2002 (Sr-90, pCi/L)	Percent Change[a]
199-H4-11	Extraction	25.6	23.2	-9.4
199-H4-63	Compliance	38.1	20.1	-47.2
199-H4-16	Monitoring	6.9[b]	9.6	+39.3
199-H4-45	Monitoring	19.5	18.2	-6.6
199-H6-1	Monitoring	9.0	8.2	-8.2

[a](2001-2002)/2001.
[b]Value displayed is an averaged result.

Technetium-99. Only one sample collected in November 2002 was above the 900 pCi/L MCL for technetium-99. This sample was from well 199-H4-9, located north of the former 183-H Solar Evaporation Basins. The November 2001 sample from this well was characterized by 55 pCi/L technetium-99 compared to 986 pCi/L in November 2002, a 1693 percent increase. Surface remediation of this facility was completed in 1997 according to the Waste Information Data System (WIDS); however, it is possible that dust suppression water added during upgradient 2002 septic field excavation operations have remobilized vadose zone contaminants. This increase in technetium-99 parallels an increase in chromium suggesting a common source.

Uranium. Thirteen well samples collected in November 2002 were analyzed for total uranium. Only samples from wells 199-H4-9 and 199-H4-3 were above the 30 µg/L MCL. Uranium concentrations in these well samples were 54.5 µg/L and 119 µg/L, respectively. These wells are located downgradient of the former 183-H Solar Evaporation Basins. The results presented below summarize November 2001 compared to November 2002 total uranium results.

Well Name	Type	Nov 2001 (U, µg/L)	Nov 2002 (U, µg/L)	Percent Change (2001-2002)/2001*
199-H4-9	Monitoring	7.06	54.5	+672
199-H4-3	Monitoring	21.5	119	+453

*(2001-2002)/2001.

Nitrate. Twenty-one wells were sampled for nitrate in November 2002, and eight samples were above the 45 mg/L MCL. November 2001 nitrate results versus November 2002 nitrate results are summarized below for these eight wells. Four of five wells showing an increase greater than 20 percent are located downgradient of the former 183-H Solar Evaporation Basins. The reason for these significant spikes in nitrate concentration probably is related to the excavation of the septic field east of the former 183-H facility discussed above.

Well Name	Type	Nov 2001 (NO_3, mg/L)	Nov 2002 (NO_3, mg/L)	Percent Change[a]
199-H4-12A	Extraction	44.0	55.4	+25.9
199-H4-3	Monitoring	86.7	255	+194.1

Well Name	Type	Nov 2001 (NO_3, mg/L)	Nov 2002 (NO_3, mg/L)	Percent Change[a]
199-H4-46	Monitoring	40.7	53.1	+30.5
199-H4-5	Compliance	42.3	57.2[b]	+35.2
199-H4-7	Extraction	43.3	47.2[b]	+9.0
199-H4-8	Monitoring	[c]	80.1	N/A
199-H4-9	Monitoring	76.8	476	+517.2
199-H6-1	Monitoring	46.0	45.6	0.9

[a](2001-2002)/2001.
[b]Value displayed is an averaged result.
[c]Not sampled in 2001.

N/A = not available.

Appendix E presents a historical summary of contaminant and co-contaminant monitoring results.

2.5 QUALITY CONTROL RESULTS FOR 100-D AND 100-H MONITORING DATA

The QC results for the 100-HR-3 sampling activities involve field or offsite laboratory testing for hexavalent chromium or total chromium.

The highlights of QC data for CY 2002 100-D and 100-H Area sampling are summarized below. Tables listing the complete QC results are found in Appendix F.

Type Quality Control Sample	Number of Pairs	Number of Pairs <20% RPD	Percent of Pairs <20% RPD
Replicate	21	21	100%
Field/offsite laboratory split (hexavalent chromium)	20	15	75%
Field/offsite laboratory splits (hexavalent chromium/total chromium)	9	6	67%
Offsite laboratory splits (total chromium)	6	6	100%

RPD = relative percent difference.

The U.S. Environmental Protection Agency (EPA) functional guideline for field-tested replicates is ±20 percent (EPA 1988, *Laboratory Data Validation Functional Guidelines for Evaluating Inorganic Analyses*). All replicates were within acceptable limits. There are no functional guidelines for split results, but the results correlated well based on the relative percent differences (RPD).

2.6 CONCEPTUAL MODEL

2.6.1 Update of 100-D Conceptual Model

This section describes the sources of the chromium contamination in the 100-D Area, the site hydrogeology, man-made influences on flow, and the changes to the plume caused by the treatment systems.

Sodium dichromate, $Na_2Cr_2O_7$, is a corrosion inhibitor that was added to reactor coolant water during normal operations. The hexavalent form of chromium found in sodium dichromate is highly mobile and is toxic to aquatic organisms, particularly salmon fry. The trivalent form of chromium readily adsorbs to soil particles and is relatively insoluble in groundwater with a pH of greater than 6.0. For convenience, hexavalent chromium is simply referred to as "chromium" in this text, unless noted otherwise.

Coolant water containing sodium dichromate in solution leaked from retention basins and large-diameter underground piping, introducing chromium to the soil column and ultimately to groundwater. In addition, radiologically contaminated coolant water was disposed of in process effluent trenches, french drains, or cribs. In addition, chromic acid, CrO_3, is a strong oxidizer that was used to decontaminate and clean reactor equipment; the contaminated solution was then disposed to french drains. A summary of waste sites that may be a source of chromium contamination in the 100-D/DR reactor area is presented in BHI-00917, *Conceptual Site Models for Groundwater Contamination at 100-BC-5, 100-KR-4, 100-HR-3, and 100-FR-3 Operable Units*.

Known disposal and spill sites have been investigated by boring from the surface and collecting samples to detect near-surface contamination. The most recent investigation was conducted in 2000 around the sodium dichromate transfer station in the 100-D Area (PNNL-13107, *Identification of a Hanford Waste Site for Initial Deployment of the In Situ Gaseous Reduction Approach*). These investigations were not successful in locating significant near-surface chromium sources.

Typical unconfined aquifer hydrostratigraphy in the 100-D Area includes the Hanford formation, the Ringold Unit E, and the Ringold Upper Mud (RUM). The thickness of the Ringold Unit E varies significantly from north to south, and it may have been eroded locally in the north so that the Hanford formation was deposited directly on the RUM. The 100-D pump-and-treat extraction wells, 199-D8-53 and 199-D8-54A, appear to be located where the Hanford formation is deposited directly on the RUM. The unconfined aquifer in these wells is located in Hanford formation sand and gravel with locally silty intervals. These wells are characterized by high well efficiency (e.g., significant production per foot of drawdown).

In the southern part of the 100-D Area, the Hanford formation was deposited on the Ringold Unit E. The unconfined aquifer in this area is within the Ringold Unit E composed of more consolidated silt, sand, and gravel with locally cemented intervals. The wells associated with the ISRM were screened in Ringold Unit E sediments and almost universally are not as efficient (e.g., less production per foot of drawdown) as those wells screened in the Hanford formation.

A more detailed description of the 100-D Area stratigraphy is found in BHI-00917 and DOE/RL-96-84.

Groundwater flow in the 100-D Area predominantly is to the north in the pump-and-treat area and northwest in the southern part of the 100-D Area, near the ISRM. Flow direction is affected by the elevation (stage) of the Columbia River, artificial mounding caused by operational practices, and variation in the hydrostratigraphy.

Groundwater flow generally is toward the Columbia River (gaining stream) except from May through August when the elevation (stage) is higher because of increased upriver dam releases. These releases raise the stage of the river and may reverse the flow direction (a losing stream). The releases are managed to balance summer irrigation demand, power (electricity) production, and maintaining safe reservoir elevations.

Facilities that have most recently affected the groundwater flow regimes in the 100-D Area include the 120-D-1 Ponds and the 182-D Reservoir. Normal disposal practices and leakage from these facilities may have been responsible for mounding between the reactor buildings and the Columbia River. The 120-D-1 Ponds were closed to disposal in 1995. The 182-D Reservoir was drained and repaired in 1995. Injection into wells south of the 100-DR Reactor during 1995 as part of the pilot-scale pump-and-treat test also may have contributed to mounding.

In addition, the hydrostratigraphy also influences flow velocity and direction. Northeast of the ISRM barrier, there is a channel eroded through the RUM that has been filled with Ringold Unit E materials. The Ringold Unit E sediments have a higher hydraulic conductivity than the RUM materials, and therefore may act as a preferential flow channel to the north.

The original target area of the pump-and-treat system, which came on line in 1997, was a plume which extended from the 100-D and 100-DR Reactor areas north to the Columbia River (Figure 2-14). The highest chromium concentrations were about 1,300 μg/L in wells located north of the reactors. The 1997 extraction well concentrations were about 300 to 400 μg/L. The high concentration areas were within the modeled capture zone of the extraction wells. The capture zone of the pump-and-treat extraction wells was expanded in May 2002 with the addition of extraction well 199-D8-72 and the conversion of compliance well 199-D8-68 into an extraction well. These wells extended capture of the north (pump-and-treat) plume to the west to contain other high chromium areas (Figures 2-8 and 2-9).

Additional site characterization since 1995 led to the discovery of the southwest 100-D plume, which was outside the capture zone of the pump-and-treat extraction wells. The ISRM barrier was built to control this southwest plume. The southwest 100-D plume was separated from the north plume (the pump-and-treat plume) by groundwater mounds created by disposal into the 120-D-1 Ponds, leakage from the 182-D Reservoir, and possibly by injection into wells south of the 100-DR Reactor during 1995 during the pilot-scale pump-and-treat test.

Changes in flow direction caused by mound dissipation have resulted in the north plume and southwest plumes coalescing (Figure 2-14). In addition, chromium concentrations are increasing in wells that are close to the Columbia River, outside the expanded capture zone of the 100-D pump and treat, and north of the ISRM. Well 199-D5-20 in the southwest part of the plume has experienced a three-fold increase in chromium to more than 600 µg/L. This well is located about 150 m from the Columbia River.

The pump-and-treat system has removed about 130 kg of chromium from the unconfined aquifer beneath the 100-D Area. Chromium concentrations in the original extraction wells have declined to about 140 µg/L in November 2002 compared to 300 to 400 µg/L in 1997. In addition, chromium concentrations have declined from 1300 µg/L to 300 to 400 µg/L in the wells north of the reactors, namely in 199-D5-14 and 199-D5-15. These reductions in chromium mass indicate that progress has been made the last year toward meeting the interim ROD RAOs.

The highest remaining concentrations are in the southwest plume area, notably in 199-D5-39, where chromium has been measured above 5,000 µg/L. The source of this plume may be the former sodium dichromate/chromic acid transfer station upgradient (east) of well 199-D5-39.

2.6.2 Update of 100-H Conceptual Model

This section describes the sources of the chromium contamination in the 100-H Area, the site hydrogeology, man-made influences on flow, and the changes to the plume caused by the treatment systems.

Sodium dichromate, $Na_2Cr_2O_7$, is a corrosion inhibitor that was added to reactor coolant water during normal operations. The hexavalent form of chromium found in sodium dichromate is highly mobile and is toxic to aquatic organisms, particularly salmon fry. The trivalent form of chromium readily adsorbs to soil particles and is relatively insoluble in groundwater with a pH of greater than 6.0. For convenience, hexavalent chromium is simply referred to as "chromium" in this text, unless noted otherwise.

Coolant water containing sodium dichromate in solution leaked from retention basins and large-diameter underground piping, introducing chromium to the soil column and ultimately to groundwater. Specific facilities that have leaked include the 183-H Solar Evaporation Basins and the 107-H Retention Basins. A summary of waste sites, which may be a source of chromium contamination in the 100-H Reactor area, is found in BHI-00917.

The 600 Area west of 100-H also may be a source of chromium-contaminated groundwater flowing toward the 100-H Area. Two 600 Area wells, namely 699-96-43 and 699-97-43, located upgradient (west) of the 100-H Area, have been characterized by chromium concentrations near 100 µg/L since the start of pump-and-treat operations. Groundwater flows generally to the northeast across the horn of the Columbia River north of Gable Mountain; therefore, the source of contaminants approaching 100-H may be east of 100-K, 100-N, or the 100-D.

Typical unconfined aquifer hydrostratigraphy in the 100-H Area includes the Hanford formation and the RUM. The unconfined aquifer is located in the saturated Hanford formation with the top of the RUM as its base. The thickness of the unconfined aquifer at the 100-H area varies significantly as shown in Figure 2-15 (isopach map of saturated Hanford formation). Extraction wells located near the Columbia River are characterized by 3 to 4.5 m (10 to 15 ft) of saturated Hanford formation. As shown in Figure 2-15, the saturated thickness of the Hanford formation thins to as little as 0.6 m (2 ft) in the 600 Area west of the 100-H Area (699-96-43). Additional details regarding 100-H Area hydrostratigraphy are found in BHI-00917 and DOE/RL-96-84.

Groundwater flow in the 100-H Area is predominantly to the northeast. Flow direction is affected by the elevation (stage) of the Columbia River, artificial mounding caused by operational practices, and hydrostratigraphy.

Groundwater flow generally is toward the Columbia River (gaining stream) except from May through August when the elevation (stage) is higher because of increased upriver dam releases. These releases raise the stage of the river and may reverse the flow direction (a losing stream). The releases are managed to balance summer irrigation demand, power (electricity) production, and maintaining safe reservoir elevations.

Leakage from the former 107-H Retention Basins created a groundwater mound in the 100-H Area. This mound could have pushed chromium-contaminated groundwater to the west. These basins were in use until about 1965, and any mounding has since dissipated.

Hydrostratigraphy has a strong influence on aquifer conditions in the 100-H Area. The minimal thickness of the saturated Hanford formation west of the 100-H Area (0.6 to 2.1 m) in wells 699-96-43 and 699-97-43 restricts flow into the 100-H Area. In addition, a thin aquifer along the Columbia River limits drawdown in extraction wells and therefore restricts pumping rates.

The original target area of the pump-and-treat system, which came on line in 1997, was a wedge-shaped 100 μg/L chromium isopleth that extended to well 199-H3-2A and was bounded along the shoreline by the 50 μg/L chromium isopleth (Figure 2-16, 100-H). Maximum concentrations within this target area were more than 100 μg/L in 199-H3-2A. This high concentration area around 199-H3-2A moved to the near river wells in subsequent years.

The November 2002 maximum concentrations in wells within the original 100-H Area target area were 65 μg/L in compliance well 199-H4-4 and 78 μg/L in 199-H4-3. The November 2002 chromium concentration in extraction well 199-H3-2A was 16 μg/L.

The capture zone of the original extraction wells included a gap between extraction wells 199-H4-12A and 199-H4-11. This gap was closed in 2000 with the addition of well 199-H4-65. However, limitations on pumping rates in extraction wells caused by lowered water levels have reopened gaps in the hydraulic capture zone.

Mounding caused by injection into wells 199-H3-3, 199-H3-4, and 199-H3-5 has had the effect of diluting contaminant concentrations now present in monitoring wells around the injection field and in extraction well 199-H3-2A.

The pump-and-treat system has removed approximately 30.4 kg of chromium from the aquifer since startup in 1997. The total remaining chromium mass is not known. However, annual chromium mass removed has decreased from 5.5 kg in 1999 to 3.3 kg in 2002; similarly, average influent concentrations were 45 μg/L in 1999 compared to 25.5 μg/L in 2002.

2.7 CONCLUSIONS

Progress Toward Remedial Action Objectives

The pump-and-treat system continues to make significant progress toward remediating the greater than 50 µg/L contaminant plume along the 100-H shoreline by extracting groundwater before it reaches the shoreline. In addition, human receptors are protected on site using institutional controls. Details regarding the operations of the existing pump-and-treat system will be useful in evaluating continued modifications.

RAO #1: Protect aquatic receptors in the river bottom substrate from contaminants in groundwater entering the Columbia River. The RAO for compliance wells is 22 µg/L based on the 11 µg/L ambient water quality criterion in place at the time of the signing of the ROD.

Results
100-D Area

- Approximately 184.1 million L of groundwater were treated during CY 2002 and 28.72 kg of hexavalent chromium were removed.
- Chromium concentrations decreased from November 2001 to November 2002 in 100-D Area extraction wells and compliance wells.
- The hydraulic barrier separating the northern plume contained by the pump-and-treat system and the southwest plume controlled by the ISRM has dissipated and the plumes appeared to have merged.
- Numerical modeling results indicate that the extraction well network is containing the northern part of the 100-D chromium plume. This is the plume on which the pump-and-treat system design at 100-D was based.
- The northern part of the southwest chromium plume is outside capture by the pump-and-treat network and north of the ISRM barrier. Chromium has increased in well 199-D5-20 to more than 600 µg/L. This well is located about 150 m from the Columbia River.
- Strontium-90 and tritium, 100-D co-contaminants, were not detected above MCLs.

100-H Area

- Approximately 166.4 million L of groundwater were treated in CY 2002 and 3.3 kg of hexavalent chromium were removed.
- Chromium concentrations significantly increased to 44 µg/L in extraction well 199-H4-7 in November 2002 but decreased significantly from November 2001 to November 2002 in three of four compliance wells.
- Numerical modeling results indicate that the extraction well network is containing the plume along much of the 100-H shoreline. Gaps in capture largely are due to lowered

pumping rates in some wells and the shutdown of extraction well 199-H4-65 because of the minimum available saturated aquifer.

- Three 100-H wells were significantly above the strontium-90 MCLs in November 2002 with the maximum concentration 23.2 pCi/L in extraction well 199-H4-11.
- Increases in co-contaminants uranium, technetium-99, and nitrate may have been the result of adding dust suppression water during the excavation of a former septic field upgradient of the former 183-H Solar Evaporation Basins.

RAO #2: Protect human health by preventing exposure to contaminants in groundwater.

Result: The interim remedial action RODs establish a variety of institutional controls that must be implemented and maintained throughout the interim action period. These provisions include some of the following:

- Access control and visitor escorting requirements
- Signage providing visual identification and warning of hazardous or sensitive areas (new signs were placed along the river and at major road entrances at each reactor area)
- Excavation permit process to control all intrusive work (well drilling, soil excavation)
- Regulatory agency notification of any trespassing incidents.

The effectiveness of institutional controls established in each interim action ROD will be evaluated and summarized for their implementation and effectiveness annually as defined by DOE/RL-2001-41, *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions*.

RAO #3: Provide information that will lead to a final remedy.

Results: The following information will be used in determining the effectiveness of ongoing operations in reaching a final remedy:

Treatment Cost: Treatment cost for the period was $2,735,200. At a yearly production rate of 350.5 million L and 32.2 kg of chromium removed, the treatment cost equates to about $0.008/L, or $85/g of chromium removed.

System Efficiency: Removal efficiency of the treatment system exceeded 93.8 percent.

Hydraulic Impact: Numerical modeling was used to estimate the effectiveness of the capture and containment of the pump-and-treat system. The model suggests that the 100-D Area system captures groundwater from the targeted area between the extraction wells that would otherwise discharge into the Columbia River. At the 100-H Area, the model suggests that the system captures groundwater from the targeted area that would otherwise discharge into the Columbia River, except when extraction well 199-H4-65 is not operating because of a thin saturated aquifer.

Effectiveness of Contaminant Removal in Aquifer: During this reporting period, more than 350.2 million L of water were treated from the 100-HR-3 OU, which resulted in the removal of 32.2 kg of chromium. Since initiation of the system in July 1997, more than 1.53 billion L of water have been treated, resulting in the removal of approximately 161.4 kg of chromium from the 100-HR-3 aquifer.

Maintain Data: Pertinent data have been maintained in the HEIS database and in the Project Specific Database.

System Availability: Total system availability for CY 2002 was 99.8 percent (time on-line/total hours during the year minus scheduled outages). The on-line availability was slightly less at 97.0 percent (time on-line/total hours during the year). This is a slight decrease from the on-line availability reported for CY 2001 (97.3 percent).

2.8 RECOMMENDATIONS

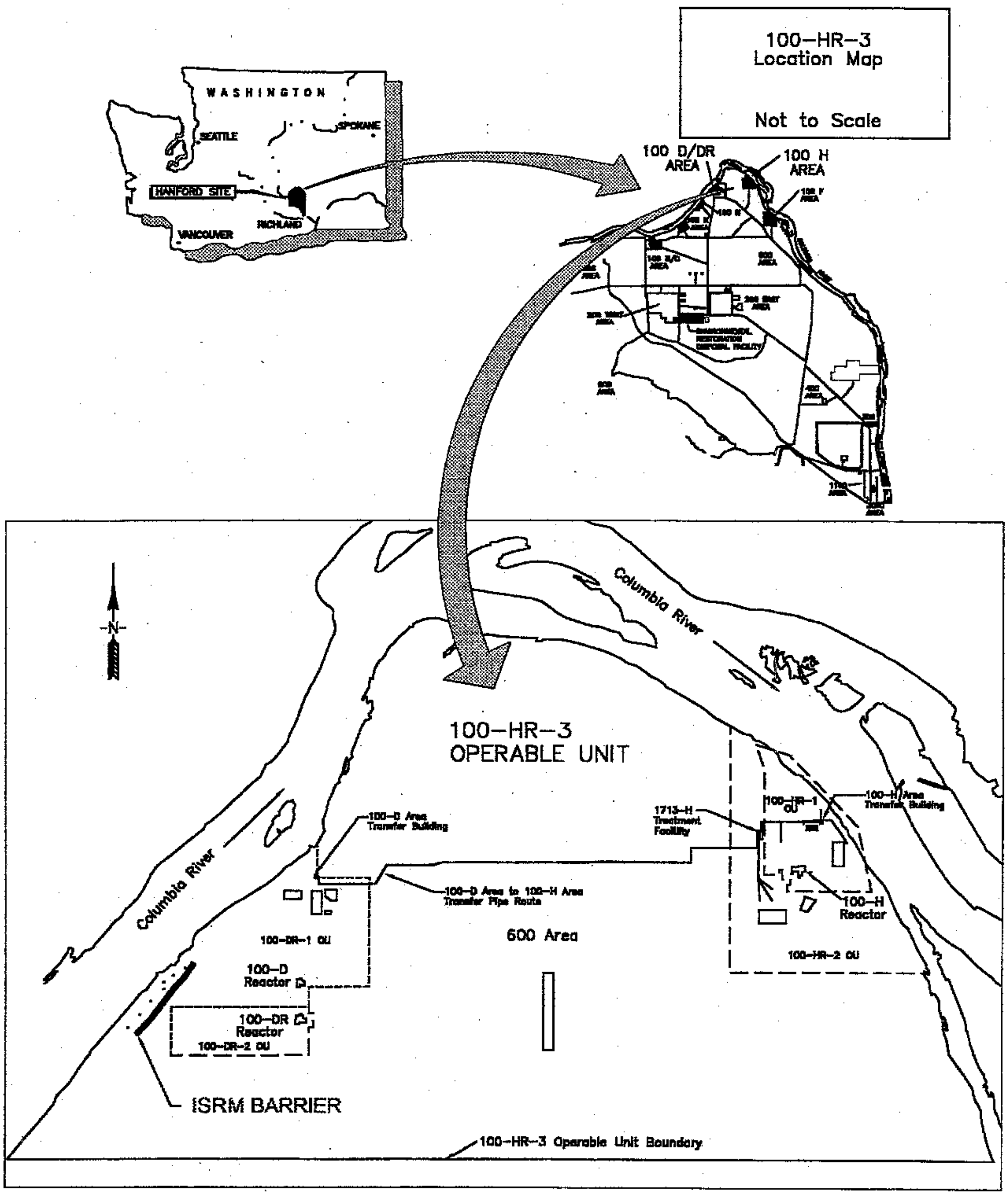
2.8.1 100-D Area

- Continue pump-and-treat operations in the northern part of the plume.
- Install monitoring wells near the 182-D Reservoir to better delineate the chromium plume in this area. This portion of the plume may be reaching the Columbia River. Design the wells so that they may be used as extraction wells, if needed.
- Install aquifer-sampling tubes along the Columbia River to determine whether the plume downgradient of well 199-D5-20 is entering the Columbia River.

2.8.2 100-H Area

- Evaluate the placement of injection wells closer to the greater than 50 µg/L portion of the plume to increase the hydraulic gradient and accelerate remediation of the aquifer. This evaluation will use a cost benefit analysis for impacts to the cleanup schedule, hydrology, treatment cost, and system efficiency and effectiveness.
- Monitor chromium concentration ranges for an extended period while pumping wells 699-97-43 and 699-96-43. Chromium concentrations have remained high in these wells since the startup of pump-and-treat operations in 1997. It is important to establish what impact this plume would have on the river if the injection wells were shut off and the natural groundwater flow in this area is allowed to equilibrate.
- Evaluate the long-term use of extraction well 199-H4-65 as part of the 100-H extraction well network. Redesign or replace if necessary for capture. Reconfigure as a monitoring well if it is no longer usable as an extraction well.

Figure 2-1. 100-HR-3 Operable Unit Layout.



1H:0113998.DWG

Figure 2-2. 100-HR-3 Operable Unit, 100-D Area Wells, and Aquifer Sampling Tubes.

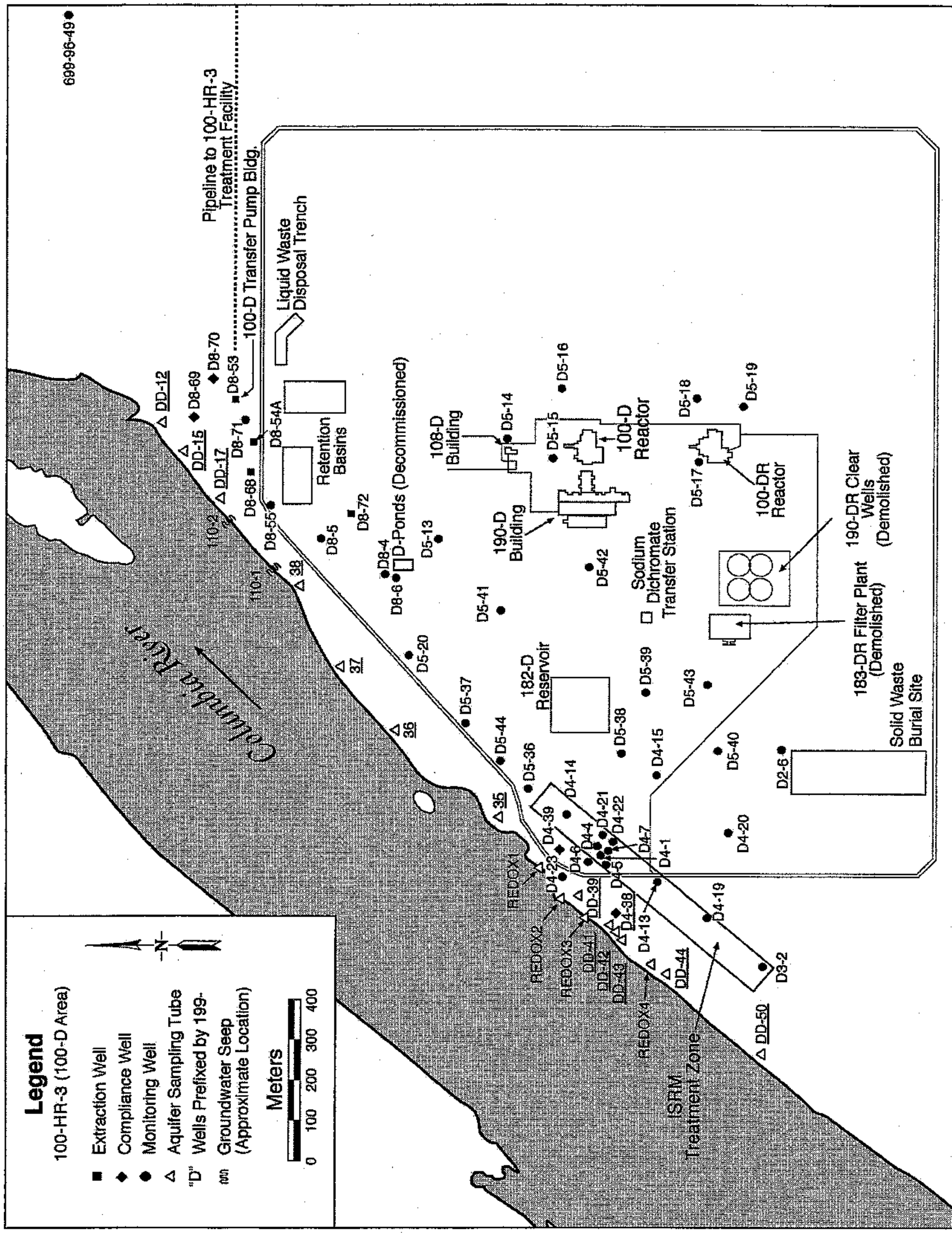
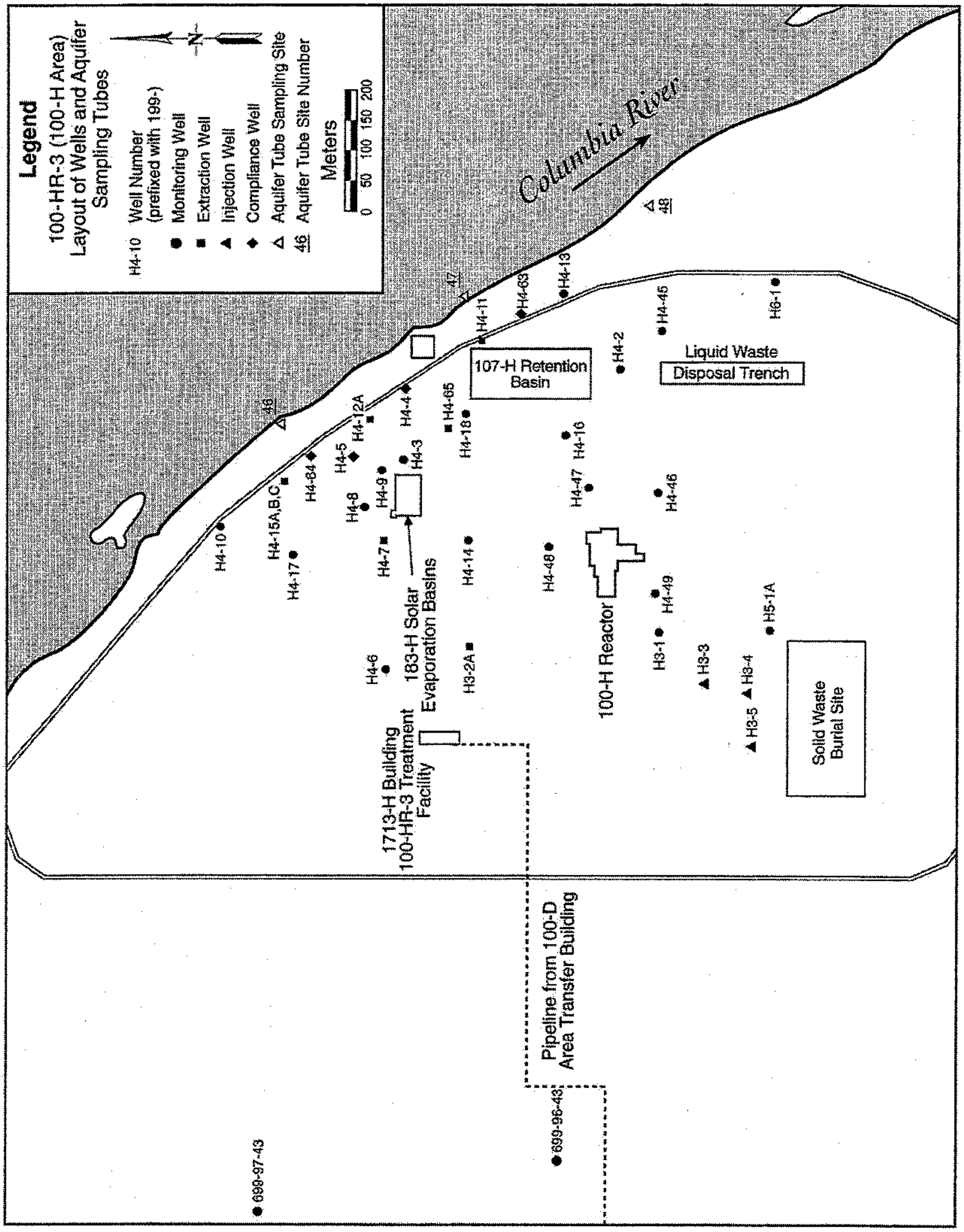
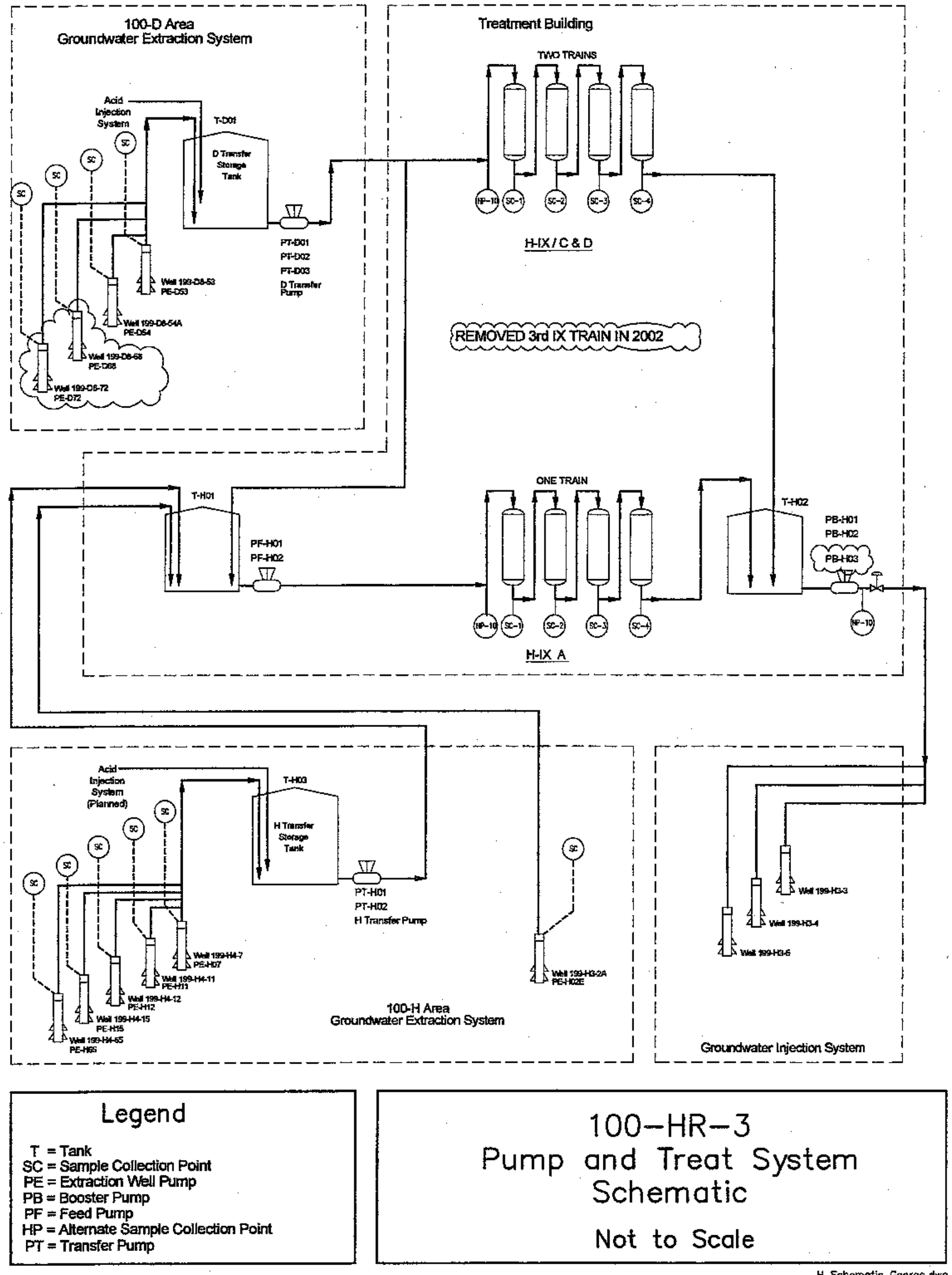


Figure 2-3. 100-HR-3 Operable Unit, 100-H Area Wells, and Aquifer Sampling Tubes.



E0205086

Figure 2-4. 100-HR-3 Operable Unit Pump-and-Treat System Schematic.



CLOUD AREA REPRESENTS CERCLA UPGRADES IN 2002

Figure 2-5. 100-HR-3 Pump-and-Treat Trends of Average Removal Efficiencies.

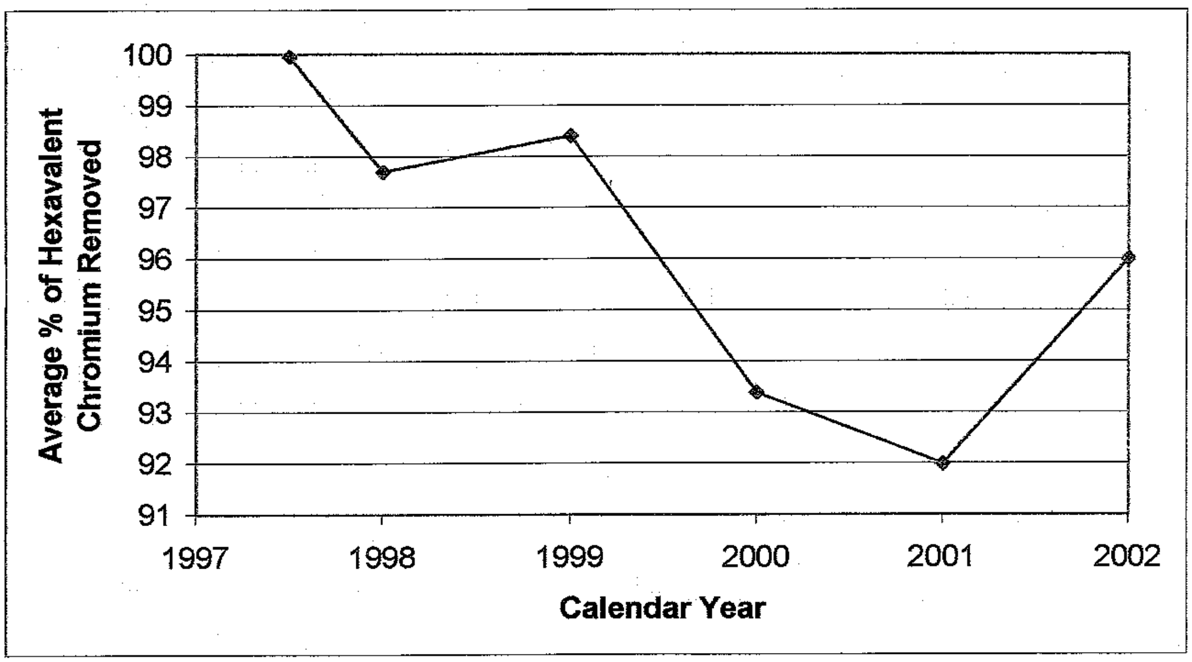
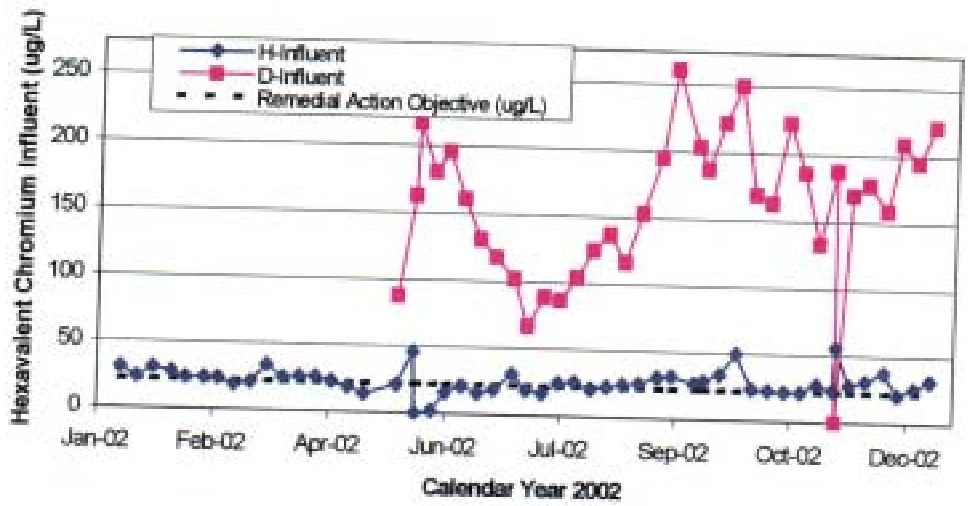


Figure 2-6. 100-HR-3 Pump-and-Treat Trends of Influent and Effluent Hexavalent Chromium Concentrations.



D-Influent values prior to May 13, 2002 are not included because they represent concentrations collected from individual well heads. Values after May 13, 2002 are composite results.

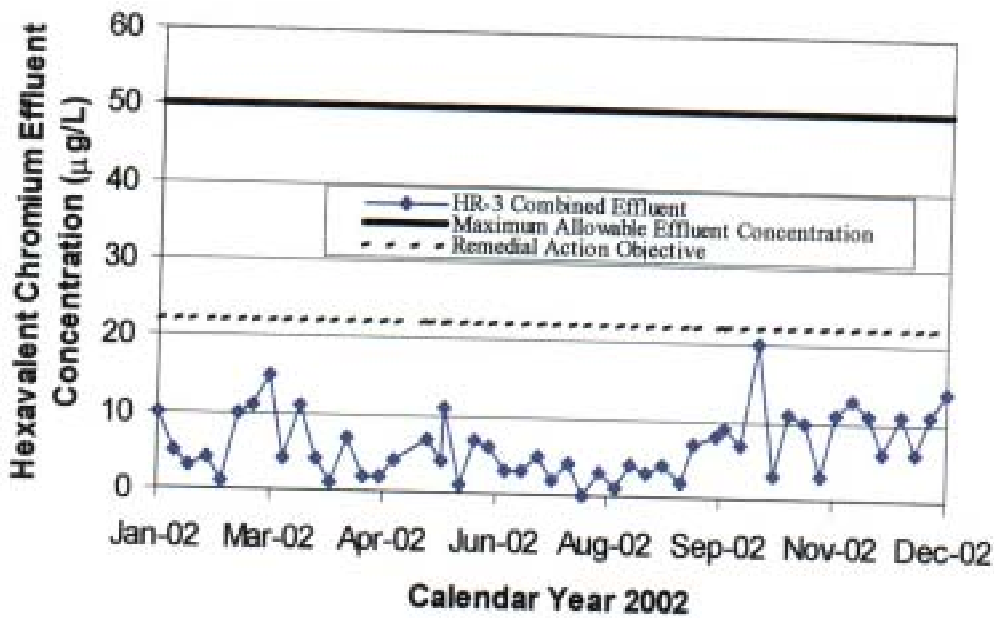
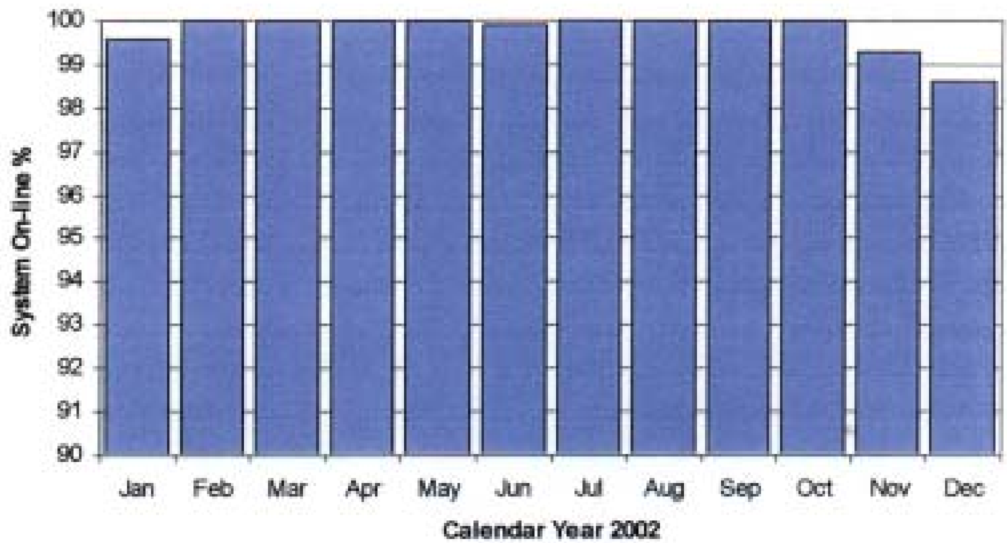


Figure 2-7. 100-HR-3 System Availability and On-Line Percentages.



Significant outages included the following:

- January 31: Power outage shut down system for 19 hours.
- March 1: Shut down system for approx. 4 hours for electrical work and upgrade.
- May 6: Shut down H transfer for 3.5 days for booster pump work.
- May 15: System shut down for testing and programming.
- June 3: Shut down H transfer for reprogramming. Weather caused leak detection alarm to shut down D transfer over the weekend.
- June 5: Shut down system for a total of 2 hours for upgrades on leak detection system.
- July 3: System down for approx. 14 hours due to power outage.
- October 3: Power outage caused system to shut down for 14.5 hours.
- November 4: Power outage occurred at approx. 1630 hours in 100 Areas.
- November 20: A leaky valve in the process building tripped off the leak detection system for 4.5 hours.
- December 11: System shut down for approx. 3 hours due to leak detection.
- December 27: System shut down due to leak detection for approx. 6 hours.

Figure 2-8. Estimated Steady-State Hydraulic Capture Zone Development by 100-HR-3 Operable Unit 100-D Area Extraction Wells.

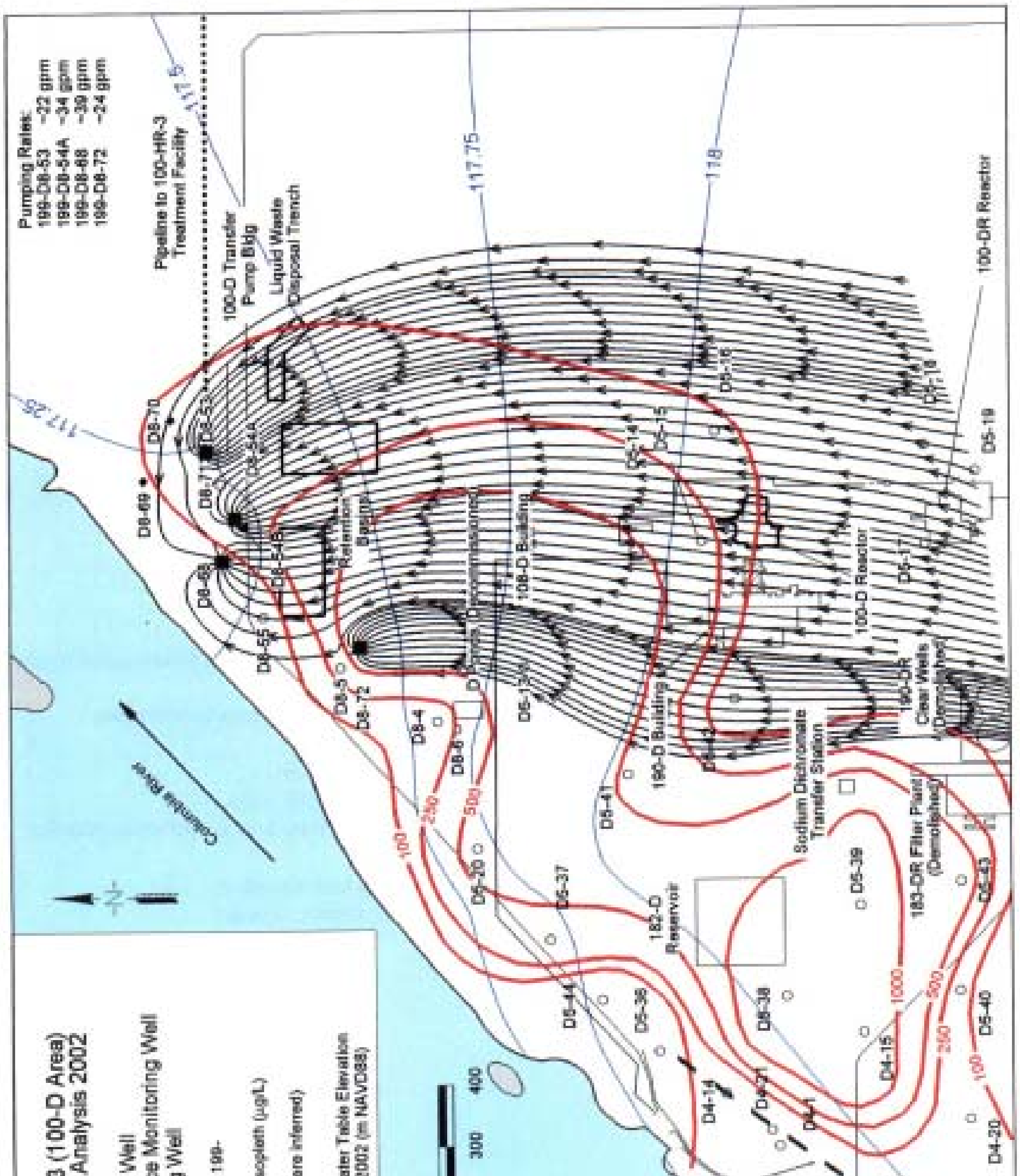


Figure 2-9. Evaluation of 100-HR-3 (100-D Area) Hydraulic Capture Using Water Particle Flow Analysis.

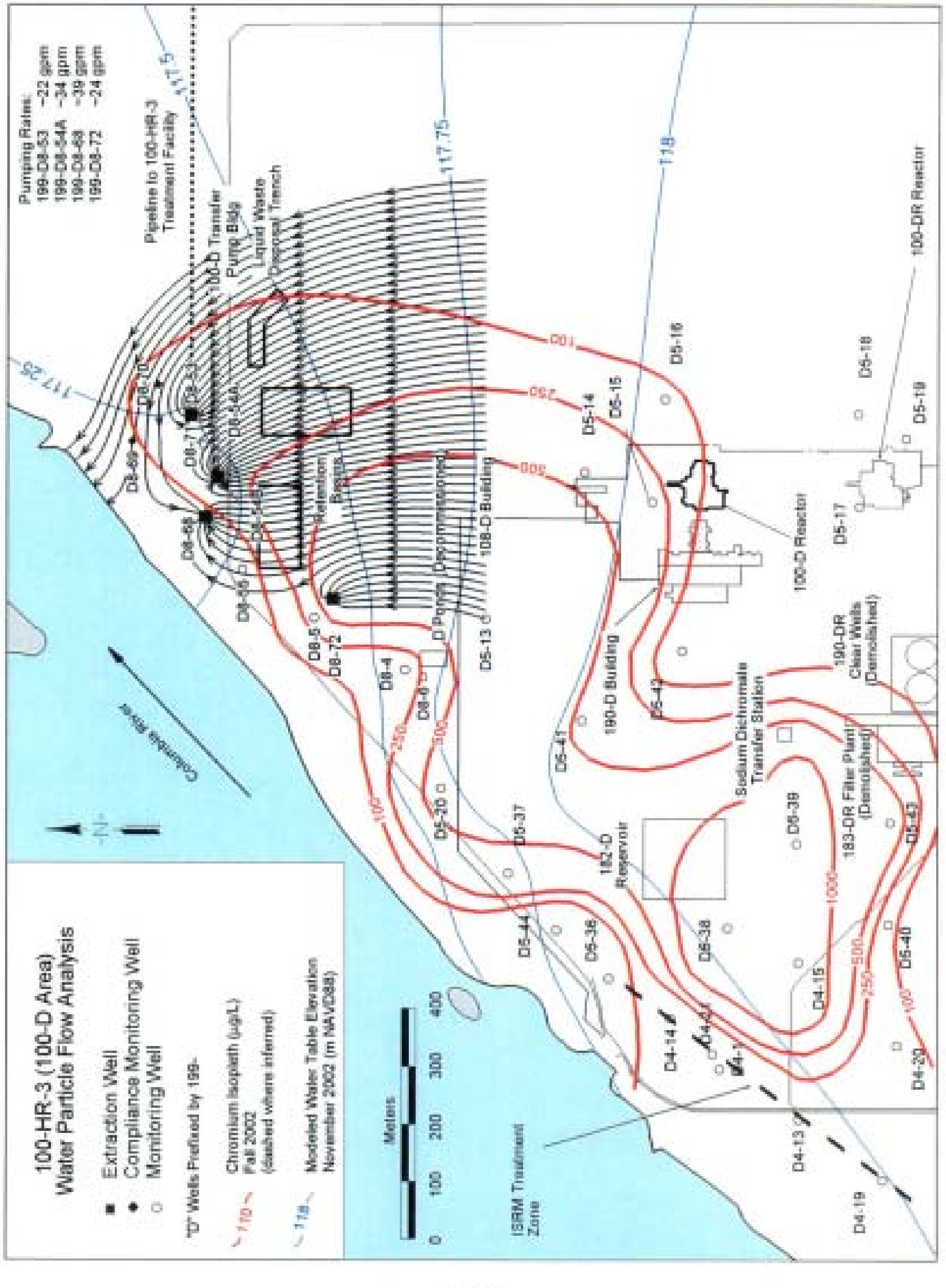


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Figure 2-10. 100-D Area 2002 Chromium Plume Map.

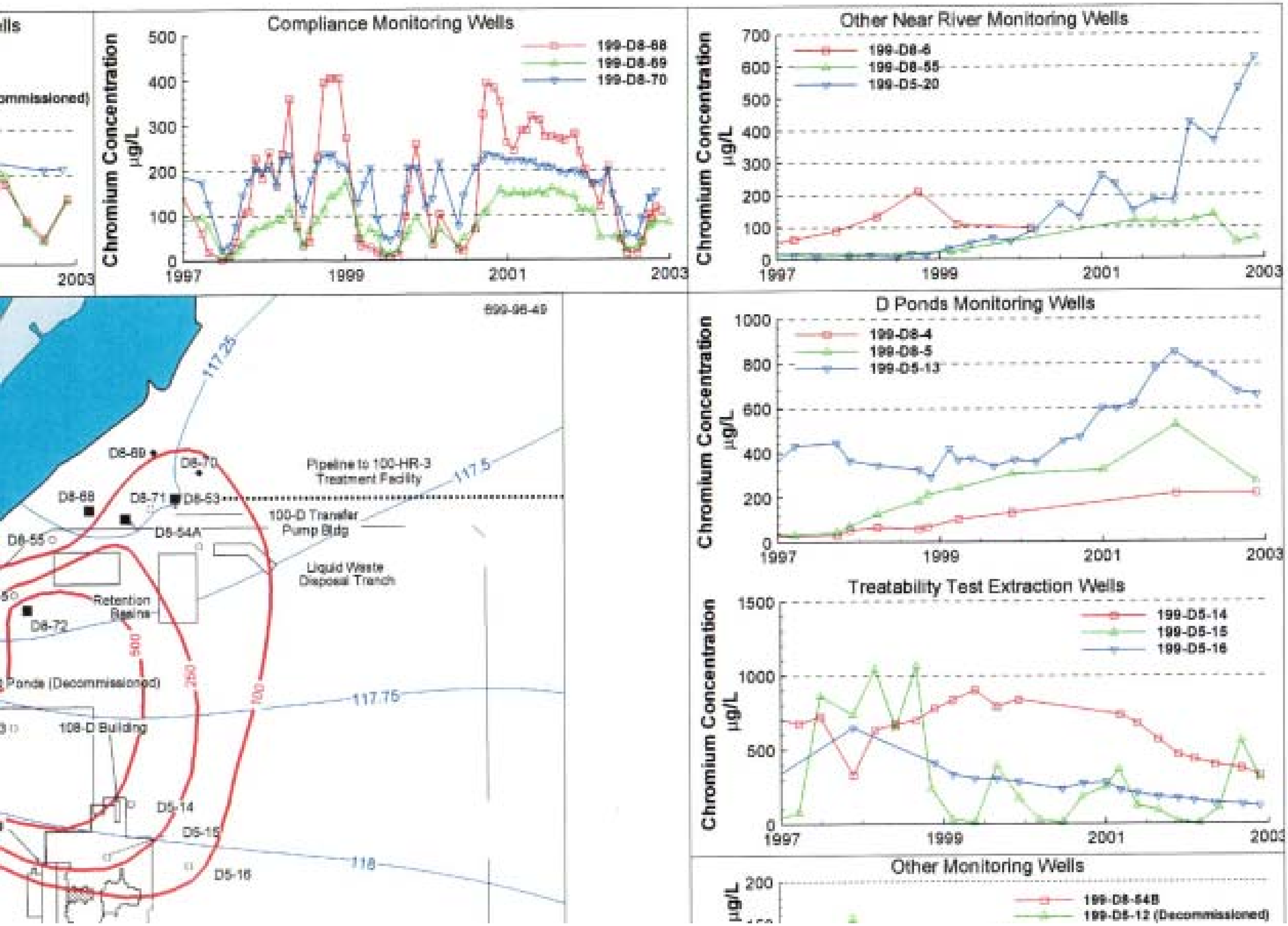

Figure 2-11. Estimated Steady-State Hydraulic Capture Zone Developed by 100-HR-3 Operable Unit 100-H Area Extraction Wells.

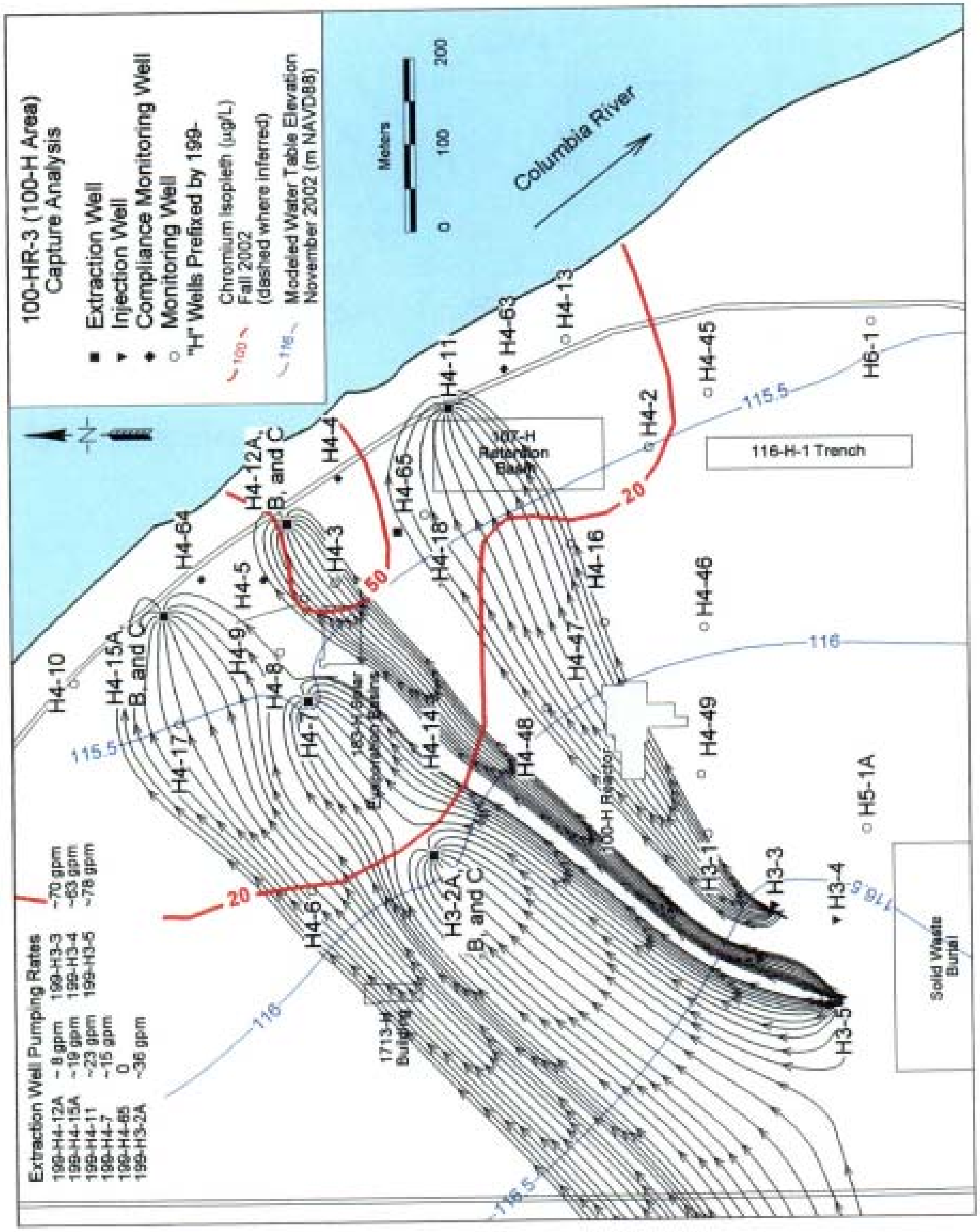

Figure 2-12. Evaluation of 100-HR-3 (100-H Area) Hydraulic Capture Using Water Particle Flow Analysis.

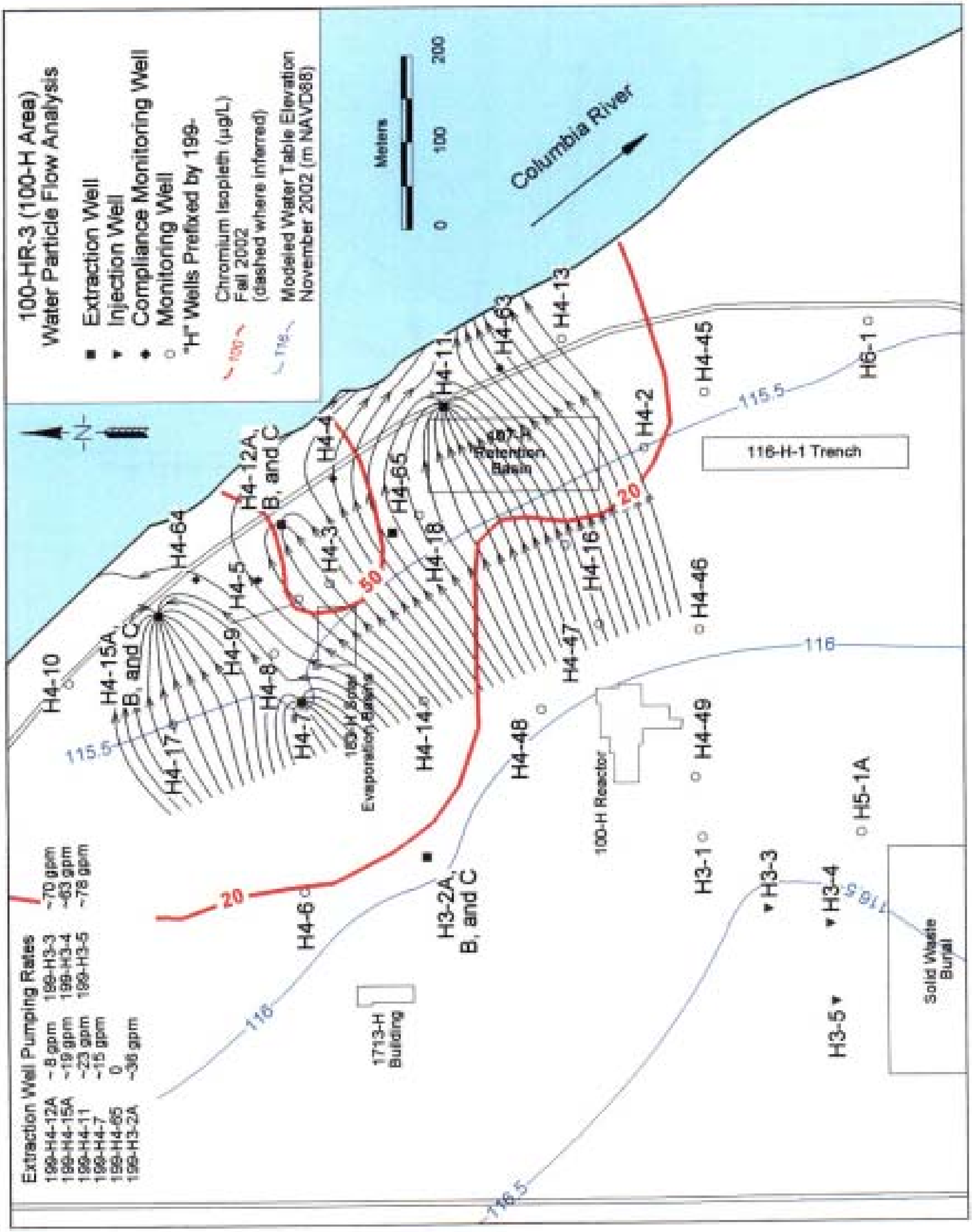

Figure 2-13. 100-H Area 2002 Chromium Plume.

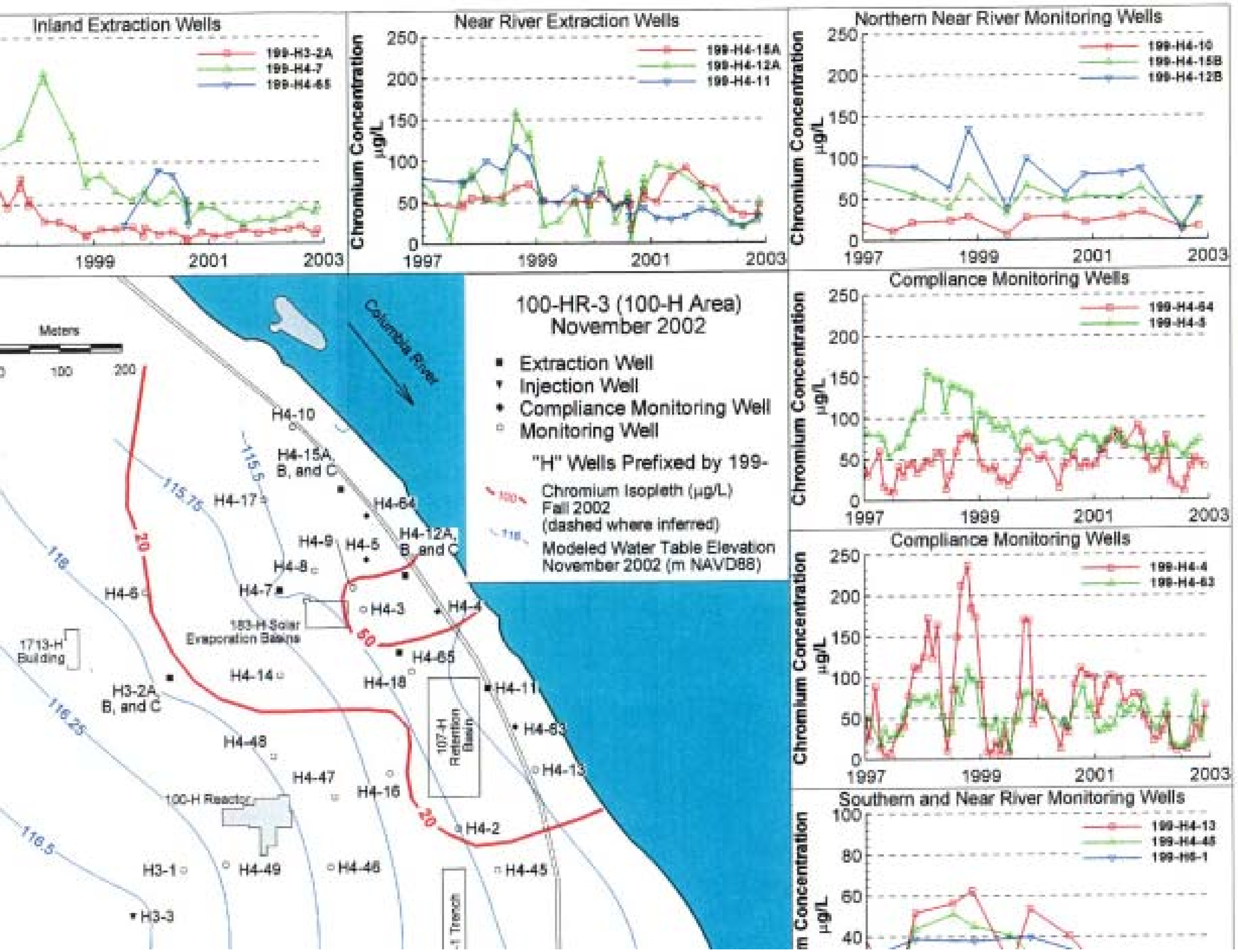

Figure 2-14. 100-D 1995 and 2002 Chromium Plume Map.

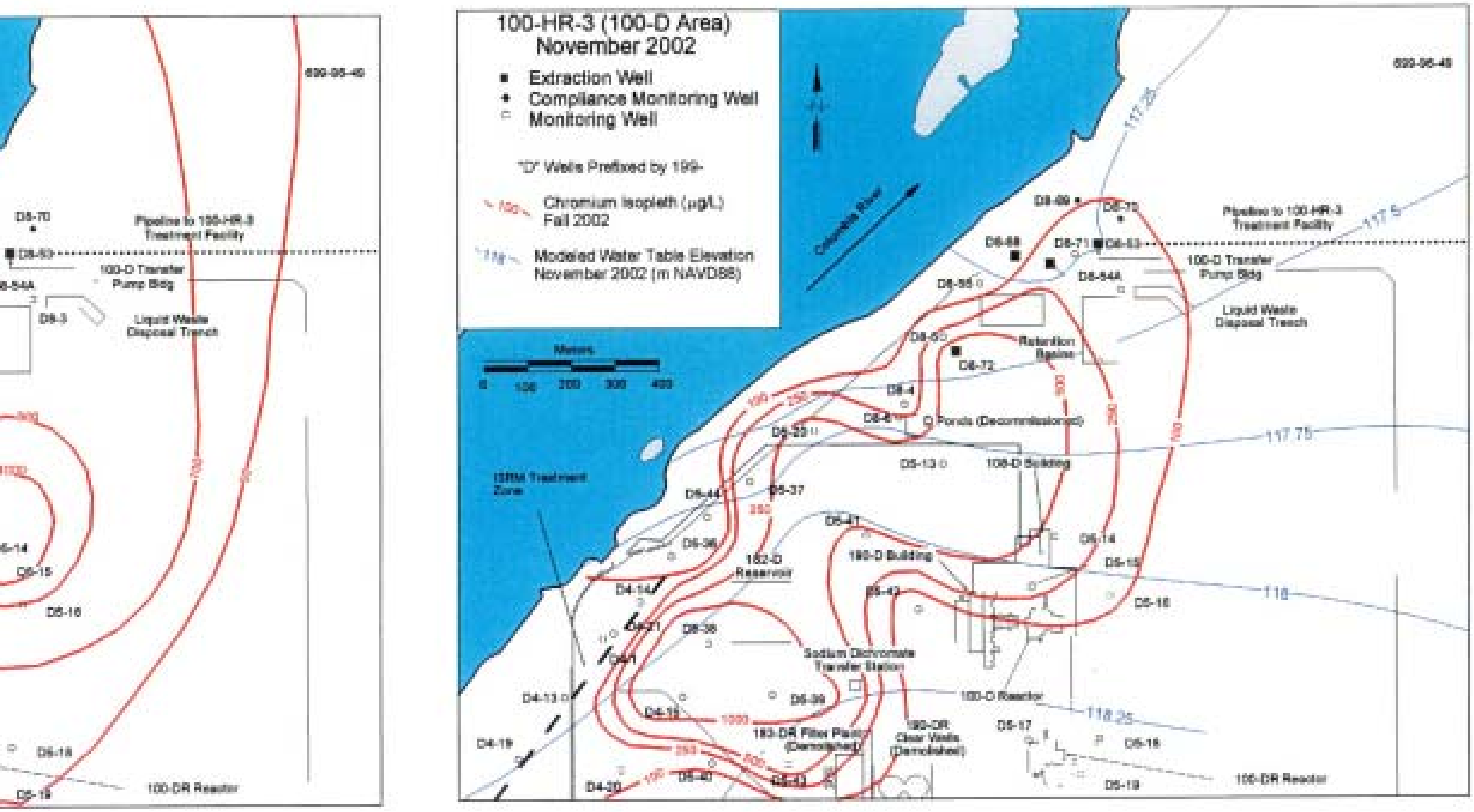

Figure 2-15. Saturated Thickness of Uppermost Aquifer Underlying the 100-H Area.

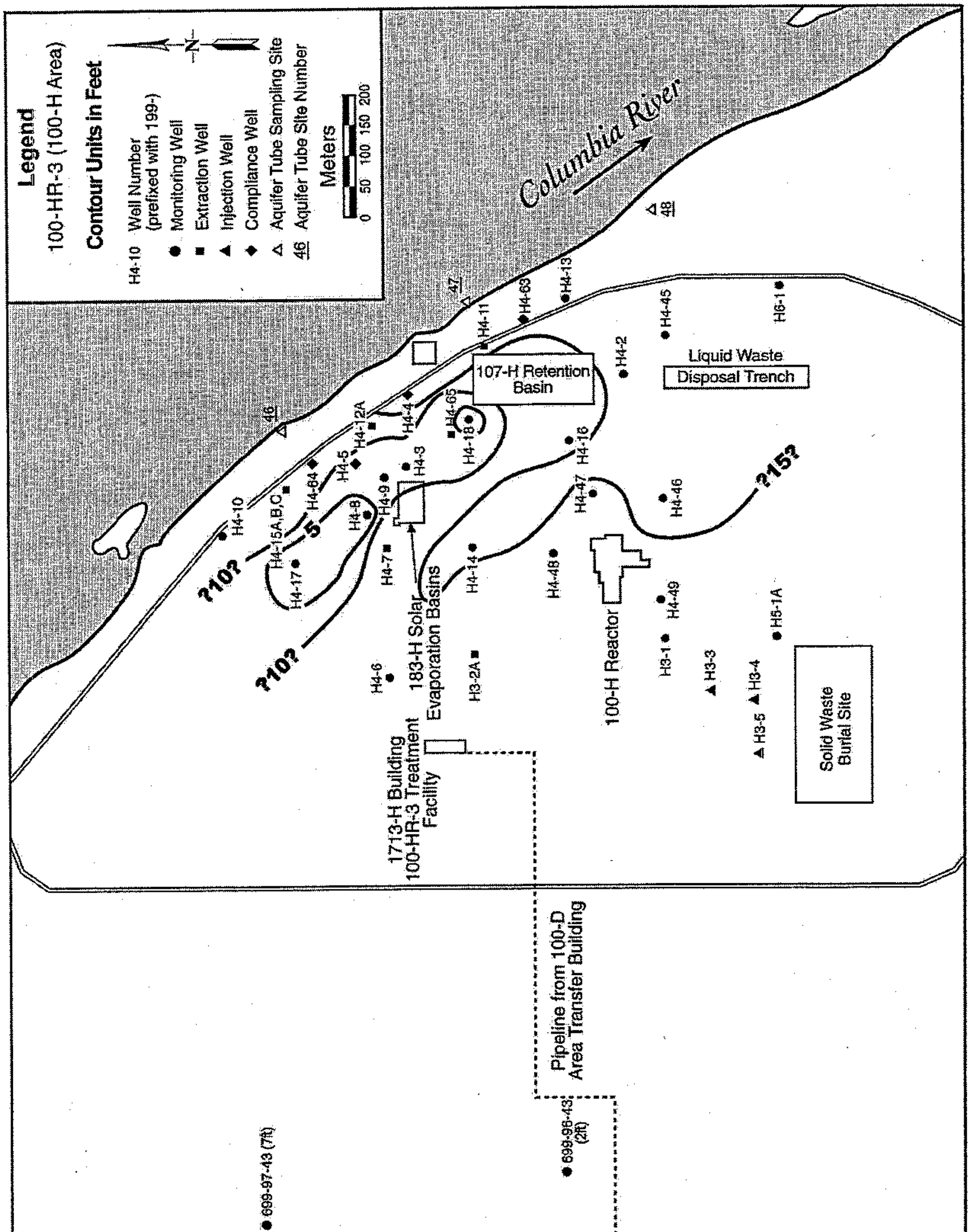

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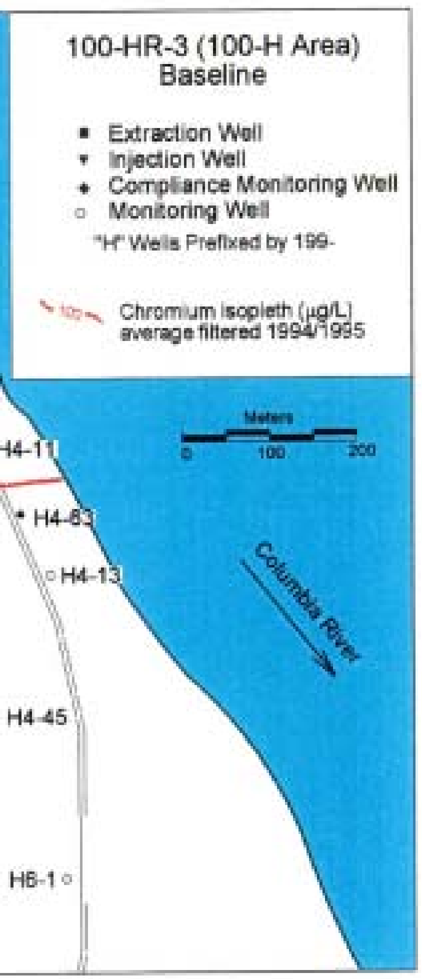
Figure 2-16. 100-H 1995 and 2002 Chromium Plume Map.



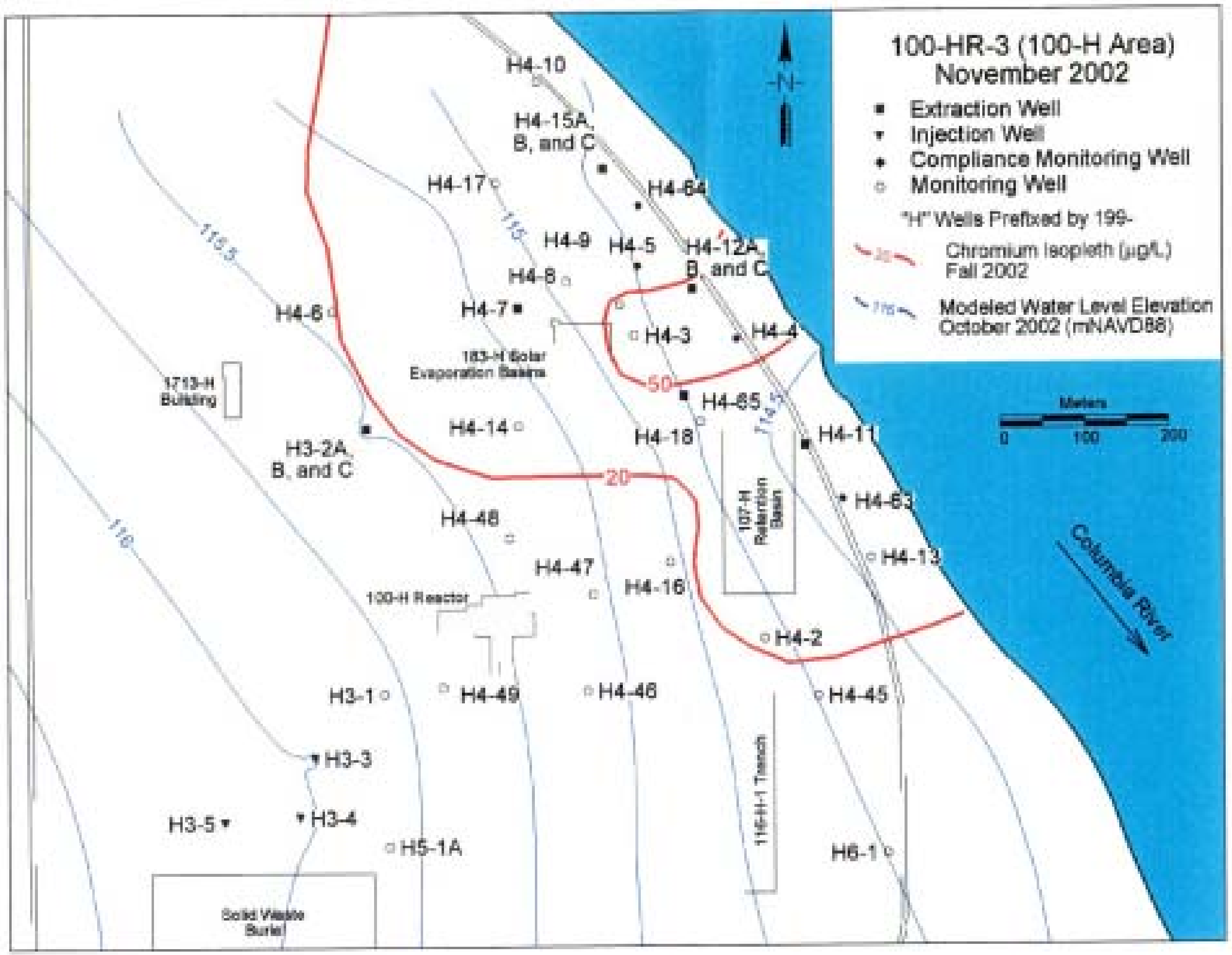


Table 2-1. 100-HR-3 (100-H and 100-D Areas) Water-Level Data and Results of the Drawdown/Buildup Analysis Used to Develop and Calibrate Numerical Groundwater Flow Models. (2 sheets)

Well	Model Analysis November 2002		Measured Water-Level Elevation Nov 2002 (m NAVD88*)	Modeled Water-Level Elevation Nov 2002 (m NAVD88*)	Drawdown/Buildup Analysis April – May 2002			
	Extraction Rate (L/min)	Injection Rate (L/min)			Extraction Rate (L/min)	Injection Rate (L/min)	Drawdown (m)	Buildup (m)
100-H Area								
199-H3-2A	137	---	115.99	115.83	52	---	0.04	---
199-H4-7	57	---	115.04	115.26	42	---	0.46	---
199-H4-11	87	---	114.78	115.08	72	---	0.26	---
199-H4-12A	31	---	114.57	115.24	71	---	0.22	---
199-H4-15A	71	---	115.37	115.24	73	---	0.38	---
199-H4-65	0	---	115.56	115.38	0	---	0.03	---
199-H3-3	---	264	116.53	116.63	---	71	---	0.05
199-H3-4	---	240	116.58	116.67	---	155	---	0.05
199-H3-5	---	297	115.99	116.78	---	77	---	N/A
199-H3-2B	---	---	115.94	115.91	---	---	0.03	---
199-H3-2C	---	---	---	---	---	---	0.02	
199-H4-4	---	---	115.41	115.28	---	---	0.05	---
199-H4-5	---	---	115.45	115.33	---	---	0.07	---
199-H4-8	---	---	115.49	115.44	---	---	0.05	---
199-H4-10	---	---	115.39	Fixed	---	---	0.03	---
199-H4-12B	---	---	115.21	115.27	---	---	0.05	---
199-H4-12C	---	---	---	---	---	---	0.02	---
199-H4-15B	---	---	115.24	115.27	---	---	0.11	---
199-H4-63	---	---	115.05	115.18	---	---	0.05	---
199-H4-64	---	---	115.33	115.29	---	---	0.03	---
199-H4-49	---	---	116.39	116.22	---	---	---	0.01
199-H5-1A	---	---	116.52	115.67	---	---	---	0.04
100-H River	---	---	115.30	---	---	---	---	---

Table 2-1. 100-HR-3 (100-H and 100-D Areas) Water-Level Data and Results of the Drawdown/Buildup Analysis Used to Develop and Calibrate Numerical Groundwater Flow Models. (2 sheets)

Well	Model Analysis November 2002		Measured Water-Level Elevation Nov 2002 (m NAVD88*)	Modeled Water-Level Elevation Nov 2002 (m NAVD88*)	Drawdown/Buildup Analysis April – May 2002			
	Extraction Rate (L/min)	Injection Rate (L/min)			Extraction Rate (L/min)	Injection Rate (L/min)	Drawdown (m)	Buildup (m)
100-D Area								
199-D8-53	83	---	116.65	117.17	154	---	0.70	---
199-D8-54A	130	---	116.53	117.08	152	---	0.69	---
199-D8-68	148	---	117.09	117.05	80	---	0.84	---
199-D8-72	92	---	N/A	117.23	149	---	0.50	---
199-D8-69	---	---	117.20	117.23	---	---	0.02	---
199-D8-70	---	---	117.21	117.28	---	---	0.07	---
199-D8-71	---	---	117.21	117.24	---	---	0.08	---
100-D River	---	---	117.64	---	---	---	---	---

*NAVD88, 1983, *North American Vertical Datum of 1988*, National Geodetic Survey, Federal Geodetic Control Committee, Silver Springs, Maryland.

N/A = not available.

3.0 100-KR-4 PUMP-AND-TREAT SYSTEM

The 100-KR-4 pump-and-treat facility is located along the Columbia River, several miles southwest of the 100-HR-3 OU (Figure 3-1). The 100-KR-4 OU is one of three OUs associated with the 100-K Area and includes the groundwater underlying the 100-KR-1 and 100-KR-2 source OUs. The 100-KR-4 treatment system and injection/extraction well field is located northeast of the KE Reactor and adjacent to the 116-K-2 mile-long disposal trench. A map of well, seep, and aquifer tube locations in the 100-K Area is presented in Figure 3-2. Appendix A provides a history of operations in the development of the 100-KR-4 pump-and-treat system.

The 100-KR-4 interim action is similar to the 100-HR-3 interim action in that the primary COC is hexavalent chromium. Interim action co-contaminants in the 100-KR-4 include tritium and strontium-90.

This section provides the annual performance report for 100-KR-4 for the reporting period of January 1 through December 31, 2002. The section is arranged in five subsections. Section 3.1 summarizes concurrent source area remedial actions within the OU and other operational changes pertaining to pump-and-treat activities. The aquifer tube results will be included in the semiannual report coming out this summer. Some of the tubes were not sampled until January 2003. Section 3.2 summarizes the treatment system performance, system operations, extraction well operations, and operational sampling. An evaluation of the aquifer response including hydraulic monitoring, numerical modeling, and contaminant monitoring is discussed in Section 3.3. Section 3.4 presents conclusions on progress toward achieving each RAO and the performance criteria. Section 3.5 provides recommendations to change/enhance the 100-KR-4 OU pump-and-treat system. Cost information is presented separately in Section 5.0.

3.1 CONCURRENT ACTIVITIES

Concurrent activities that were completed in CY 2002 for the 100-KR-4 OU include the following:

- Aquifer tube sampling was conducted along the low-water shoreline of the 100-K Area during November 2002. Data will be reported in the CY 2003 semi-annual technical memorandum for 100-HR-3, 100-KR-4, and 100-NR-2
- Design activities for converting 199-K-126 from a monitoring to an extraction well began in October 2002. Evaluation of monitoring results and capture zone analysis determined that elevated levels of chromium around 199-K-126 could be cost effectively contained by conversion to an extraction well. The well was made operational in January 2003.
- Planning and design activities for the replacement of extraction well 199-K-112 and construction of a new compliance well were conducted in CY 2002. Excessive sanding problems in 199-K-112 limited extraction pumping rates. Therefore, it was determined that replacement well 199-K-129 should be constructed. Compliance well 199-K-130 was planned and designed to help refine the northern extent of the chromium plume. Both wells will be constructed and brought on-line in CY 2003.

- The 116-KW-3 Retention Basin tank bottom and associated contaminated soils were removed.
- The feeder pipes and contaminated soils associated with the 116-K-2 Trench were removed.

3.2 100-KR-4 TREATMENT SYSTEM PERFORMANCE

This section describes the 100-KR-4 pump-and-treat system operations and sampling activities that occurred from January 1 through December 31, 2002. Specific details include system availability, changes to the system configuration, mass of contaminants removed during operations, contaminant removal efficiencies, quantity and quality of extracted and disposed groundwater, waste generation, and contaminant trends. A detailed discussion of this information is presented in the associated section appendices.

As a result of the CERCLA 5-year review, extraction well 199-K-127 was added in April 2002 to improve capture and containment of the hexavalent chromium plume. The additional flow from this new well exceeded the design capacity of the existing treatment system, requiring the addition of one ion-exchange skid that was transferred from 100-HR-3 and reinstalled at the KR-4 Treatment Process Building. The current configuration consists of three skids with 12 vessels. Injection well 199-K-128 was added in May 2002 to balance injection and extraction capacity. A third feed pump and booster pump were added at the 100-KR-4 Process Building to provide operational redundancy and increase system availability. Figure 3-3 presents the current system schematic of the pump-and-treat system.

A summary of operational parameters and total system performance for CY 2002 is presented below:

Total processed groundwater:	
Total amount of groundwater treated (since October 1997 startup) (billion L)	1.69
Total amount of groundwater treated during CY 2002 (million L)	445.7
Mass of hexavalent chromium removed:	
Total amount of hexavalent chromium removed (since October 1997 startup) (kg)	184.1
Total amount of hexavalent chromium removed in CY 2002 (kg)	35.3
Summary of 2002 operational parameters:	
Removal efficiency (% by mass)	95.2%
Waste generation (m^3)	58
Regenerated resin installed (m^3)	25.3
New resin installed (m^3)	55.2
Number of resin changeouts	35

Summary of 2002 system availability:	
Total time online (hours)	8,255.5
Total possible run time (hours)	8,760
Scheduled down time (hours)	359.5
Unscheduled down time (hours)	145
On-line availability (%)	94.3
Total system availability (%)	98.3

- The removal efficiency ((influent-effluent)/influent) for CY 2002 was 95.2 percent, which is slightly lower than the 95.6 percent reported for CY 2001 (Figure 3-4).
- The 100-KR-4 influent hexavalent chromium concentration average of 84 μg/L was lower than the CY 2001 average of 114 μg/L.
- The average effluent hexavalent chromium concentration for CY 2002 was 4 μg/L, which was comparable to the 5 μg/L in CY 2001. Trend plots of CY 2002 influent and effluent concentrations are presented in Figure 3-5.
- The maximum hexavalent chromium concentration in the effluent was 10 μg/L.
- Total system availability for CY 2002 was 98.3 percent (time on-line/total hours during the year minus scheduled outages), which was higher than the 97 percent reported in CY 2001. The on-line availability was 94 percent (time on-line/total hours during the year). This is a slight decrease from the on-line availability reported for CY 2001 of 96 percent. Significant outages for CY 2002 are detailed in Figure 3-6.

The following table compares the flow rates from wells at the 100-KR-4 pump-and-treat system.

Well No.	Recommended Flow Rate (gal/min)	Yearly Avg Flow Rate (gal/min)	Current Flow Rate (gal/min)
K-112A	25	20.1	28
K-113A	25	14.0	13
K-115A	25	37.4	44
K-116A	40	40.5	44
K-119A	30	26.3	30
K-120A	30	27.0	30
K-125A	30	32.8	40
K-127	40	37.9	40

The recommended flow rates are based on the numerical model that was updated consistent with the CERCLA 5-year review design modifications. The yearly average flow rates are calculated from actual totalized volumes extracted divided by the total hours in a year (except well 199-K-127, which became operational on June 1, 2002 – the total hours considered is June 1 through December 31, 2002). This average reflects system or equipment down time. The current flow rates are the continuous operating conditions to which the system is currently set and has been since June 1, 2002.

This comparison shows that wells K-115A, K-116A, and K-125A were pumped at greater flow rates than recommended. (Wells K-115A and K-116A are pumped at the design limits of the extraction pumps.) Because these wells could sustain these higher yields during the reporting period, they were maintained at these levels to help offset the lower rates from wells K-112A and K-113A. During the year, all wells were subject to down time due to area power-grid outages, equipment failures or maintenance, and construction activities. In addition, the lower river levels throughout the year resulted in much down time for well K-113A (along with a reduction in the effective flow rate available from the well). The average flow rate from well K-112A appears low, reflecting a problem with intake of excessive sand.

Historical presentation of operational parameters, total system performance, and extraction well chromium concentration and extraction rates can be found in Appendix B.

3.3 AQUIFER RESPONSE IN THE 100-K AREA

This section describes the general hydrogeologic conditions in the 100-K Area, numerical modeling conducted to evaluate the extraction well network, and changes in contaminant concentrations in monitoring wells.

3.3.1 Hydrogeologic Conditions

Groundwater flow direction in the 100-K Area throughout the year was generally to the northwest (toward the Columbia River) except from May through August when river stage is higher and the flow may be reversed or parallel to the river. The average river stage elevation during November 2002 was 118.046 m compared to a lower average 1991-2002 November river stage elevation of 117.771 m. The average November 2002 hydraulic gradient was 0.002 toward the northwest. However, the hydraulic gradient and flow direction do change throughout the year due to fluctuations in river stage. It should be noted that infiltration of river water does impact analytical results for some near-river wells. The estimated flow velocity ranged from 0.03 m/day in the injection field area to 3 m/day around extraction well 199-K-116A. This velocity is based on hydraulic conductivities ranging from 2 m/day to 200 m/day and a porosity of 15 percent. Additional information summarizing the hydrogeologic condition and aquifer response in the 100-K Area is presented in Appendix C.

3.3.2 Numeric Modeling and Field Validation

Numerical modeling results indicate that contaminated groundwater was captured and prevented from discharging into the Columbia River along most of the 100-K Area shoreline downgradient of the 116-K-2 trench. The conversion of compliance well 199-K-126 to an extraction well in January 2003 will provide additional capture where previous modeling indicated chromium may reach the river (Figures 3-7 and 3-8).

Water-level measurements in 100-K Area monitoring wells help establish the zone of influence of the extraction wells. Eight monitoring wells are equipped with pressure transducers and data loggers. The maximum drawdown in a monitoring well is 0.7 m in 199-K-21. Buildup in the injection wells reached a maximum of 6.86 m in 199-K-123A. Hydraulic conductivities used in the modeling were very low (2 m/day) in the injection well area; the low hydraulic conductivities help explain the significant buildup measured in these injection wells. A complete listing of drawdown calculated from water-level data and estimated drawdown from the model for specific wells is found in Table 3-1.

A more detailed discussion of model development is found in Appendix D.

3.3.3 Contaminant Monitoring

This section summarizes and interprets analytical results obtained from groundwater monitoring wells supporting the 100-K Area pump-and-treat remedial action. Section 3.3.3.1 includes a discussion about chromium monitoring results. Section 3.3.3.2 includes a discussion about monitoring results for remedial action co-contaminants strontium-90 and tritium. Nitrate and carbon-14 are constituents of interest.

CY 2002 Highlights:

- Chromium concentrations decreased more than 20 percent in three extraction wells and two compliance wells, but remained above the RAO of 22 µg/L. Chromium concentrations increased more than 20 percent only in extraction well 199-K-120A.

- The furthest downstream compliance well, 199-K-126, had a chromium concentration of 106 µg/L in October 2002. This well became operational as an extraction well in January 2003.

- Five pump-and-treat area wells had strontium-90 concentrations above the 8 pCi/L MCL. The maximum concentration was 39.5 pCi/L in monitoring well 199-K-21.

- Three pump-and-treat area wells had tritium concentrations above the 20,000 pCi/L MCL. The maximum concentration was 85,600 pCi/L in extraction well 199-K-120A, an increase of 206 percent over 2001.

3.3.3.1 Chromium Monitoring Results. Chromium concentrations are monitored in eight extraction wells, five compliance wells, and seven monitoring wells in the pump-and-treat operational area. Additional CERCLA monitoring wells outside the area affected by pump-and-treat operations also are monitored for chromium.

The table below compares the 2001 versus 2002 chromium analytical results for extraction wells, compliance wells, and selected monitoring wells impacted by pump-and-treat operations. The results below are filtered hexavalent chromium field analytical results, except as noted. Figure 3-9 shows the October 2002 100-K Area chromium plume and associated historical trends.

Well Name	Type	October 2001 (Cr µg/L)	Fall 2002 (Cr µg/L)	Percent Change
199-K-112A	Extraction	90[a]	70[a]	-22.2
199-K-113A	Extraction	76[a]	47[a]	-75.4
199-K-114A	Compliance	104	89	-14.4
199-K-115A	Extraction	154[a]	98[a]	-36.4
199-K-116A	Extraction	164[a]	140[a]	-14.6
199-K-117A	Compliance	21	12	-42.9
199-K-119A	Extraction	76[a]	70[a]	-7.9
199-K-120A	Extraction	70[a]	84[a]	+20
199-K-125A	Extraction	82[a]	67[a]	-18.3
199-K-126	Compliance[b]	116	106	-8.6
199-K-127	Extraction	[c]	78	[c]
199-K-18	Compliance	111	113	+1.8
199-K-19	Monitoring	84	84	0
199-K-20	Compliance	86	29	-66.3
199-K-111A	Monitoring	28.7[d]	37.1[d]	+29.3
199-K-32A	Monitoring	12.7[d]	15.5[d]	+11.5
199-K-21	Monitoring	10	18	+80
199-K-37	Monitoring	65	70	+7.7
199-K-22	Monitoring	155	148	-4.5
699-78-62	Monitoring	37.5[d]	[e]	[e]

[a]Results from Project Specific Database, averaged.
[b]199-K-126 converted to extraction well in January 2003.
[c]Not operational until April 2002.
[d]Total chromium.
[e]Not sampled during 2002.

Chromium concentrations decreased from October 2001 to October 2002 in six of seven extraction wells, and decreased 20 percent or more in three extraction wells. Chromium concentrations decreased from October 2001 to October 2002 in four compliance wells, and more than 20 percent in two compliance wells. Part of the decrease in near-river compliance wells may be from dilution from the river. A significant increase in chromium concentration was detected only in extraction well 199-K-120A, which increased 20 percent.

3.3.3.2 Co-Contaminant Monitoring Results. Strontium-90 and tritium are 100-K pump-and-treat co-contaminants. Nitrate and carbon-14 are 100-K contaminants of interest that also are monitored as part of the CERCLA sampling.

Strontium-90. Fifteen wells within the 100-K pump-and-treat area are monitored for strontium-90, and five were characterized by strontium-90 above the 8 pCi/L MCL. Concentrations remained relatively unchanged this calendar year. The October 2001 results compared to October 2002 in these five wells are summarized below.

Well Name	Type	October 2001 (Sr-90, pCi/L)	October 2002 (Sr-90, pCi/L)	Percent Change*
199-K-20	Compliance	9.01	8.42	-6.05
199-K-21	Monitoring	38.9	39.5	+1.5
199-K-113A	Extraction	11.1	10.9	-1.8
199-K-115A	Extraction	9.83	8.33	-15.3
199-K-114A	Compliance	18.6	17.5	-5.9

*(2001-2002)/2001.

In addition, there are five monitoring wells in the 100-K Reactor areas in which strontium-90 is monitored. Three of these five wells were characterized by strontium-90 above 8 pCi/L with the maximum concentration of 2100 pCi/L in well 199-K-109A, down gradient of the KE fuel storage basin drain field.

Tritium. Eighteen wells are monitored for tritium in the 100-K pump-and-treat area, and four of these wells had tritium above the 20,000 pCi/L MCL in October 2002. The October 2001 tritium results are compared to the October 2002 results below for the four wells above 20,000 pCi/L in 2002.

Well Name	Type	October 2001 (H-3, pCi/L)	October 2002 (H-3, pCi/L)	Percent Change[a]
199-K-32A	Monitoring	79,400	62,900	-20.7
199-K-111A	Monitoring	97,500	62,400	-36.0
199-K-18	Compliance	38,900[b]	41,400	6.4
199-K-120A[c]	Extraction	27,800	85,600	+207.9

[a](2001-2002)/2001.
[b]Averaged result.
[c]Well sampled in November.

It is important to note that all of the wells listed above are located at the upstream end of the 116-K-2 Trench. The source of this tritium may be from the 116-K-2 Trench and/or from a previously unknown plume beneath the 100-K Burial Ground that has been displaced to the west by the mounding created by the injection network (PNNL-14031, *Evaluation of Potential Sources for Tritium Detected in Groundwater at Well 199-K-111A, 100-K Area*).

In addition, there are five monitoring wells in the 100-K Reactor areas in which tritium is monitored. Two of these five wells were characterized by tritium above the 20,000 pCi/L MCL, with the maximum concentration of 137,000 pCi/L in well 199-K-106A. The source of this tritium probably is the KW Condensate Crib (PNNL-13788, *Hanford Site Groundwater Monitoring for Fiscal Year 2001*).

Carbon-14. Twelve wells in the 100-K area were monitored for carbon-14 during 2002. All of these wells are outside the pump-and-treat area; however, wells 199-K-111A and 199-K-32A are close to the upstream end of the 116-K-2 Trench. The maximum carbon-14 concentrations in these wells in 2001 and 2002 and the near-term trends are summarized below. The MCL for carbon-14 is 2000 pCi/L.

Well Name	Type	October 2001 (C-14, pCi/L)	October 2002 (C-14, pCi/L)	Percent Change*
199-K-111A	Monitoring	247	235	-4.8
199-K-32A	Monitoring	267	213	-20.2

*(2001-2002)/2001.

The maximum carbon-14 concentration detected in 2002 was 20,900 pCi/L in well 199-K-106A downgradient of the KW Condensate Crib, the probable source of the contamination. Other downgradient wells with elevated carbon-14 include 199-K-33 (8230 pCi/L) and 199-K-34 (4350 pCi/L).

Nitrate. Nine wells within the pump-and-treat area were monitored for nitrate during 2002. The maximum nitrate concentration was 94.3 mg/L in compliance well 199-K-18. Nearby well 199-K-111A was characterized by 60.6 mg/L nitrate; however, the other wells in the pump-and-treat area had nitrate concentration below the 45 mg/L MCL. The October 2001 versus October 2002 concentrations in the nine wells in the pump-and-treat area and the percent change are summarized below.

Well Name	Type	October 2001 (NO_3, mg/L)	October 2002 (NO_3, mg/L)	Percent Change*
199-K-111A	Monitoring	68.2	54.9	-19.5
199-K-18	Compliance	94.3	94.3	0
199-K-19	Monitoring	24.2	23.5	2.9
199-K-20	Compliance	8.93	9.74	+9.0
199-K-32A	Monitoring	21.9	24.3	+11.0
199-K-21	Monitoring	26.2	23.5	-10.3
199-K-22	Monitoring	13.5	14.6	-8.1
199-K-37	Monitoring	11.0	11.5	+4.5
199-K-117A	Compliance	5.31	1.73	-67.4

*(2001-2002)/2001.

Samples from ten monitoring wells in the reactor areas also were analyzed for nitrate in 2002. The range in concentrations was from 84.6 mg/L in 199-K-106A to 0.23 mg/L in 199-K-108A. Five of these wells were characterized by nitrate above the 45 mg/L MCL. Septic system drain fields and decontamination solutions containing nitric acid are the likely sources of this contaminant.

Appendix C presents a historical summary of contaminant and co-contaminant monitoring results.

3.4 100-KR-4 CONCEPTUAL MODEL UPDATE

This section describes the sources of the chromium contamination in the 100-K Area, the site hydrogeology, man-made influences on flow, and the changes to the plume caused by the treatment systems.

Sodium dichromate, $Na_2Cr_2O_7$, is a corrosion inhibitor that was added to reactor coolant water during normal operations. The hexavalent form of chromium found in sodium dichromate is highly mobile and is toxic to aquatic organisms, particularly salmon fry. The trivalent form of chromium readily absorbs to soil particles and is relatively insoluble in groundwater with a pH of greater than 6.0. For convenience, hexavalent chromium is simply referred to as "chromium" in this text, unless noted otherwise.

The primary source of chromium contamination in the 100-K Area is the 116-K-2 Trench. Large volumes of chromium-contaminated reactor coolant water and other reactor effluents were discharged into the trench between 1955 and 1971. The 116-K-2 Trench is approximately 1250 m long, 14 m wide, and 5 m deep, in its original configuration. The trench was excavated parallel to and about 250 m from the Columbia River (DOE/RL-96-84). A list of other potentially significant sources that may have contributed to chromium contamination in the 100-K Area is found in BHI-00917 and PNNL-14187, *Summary of Hanford Site Groundwater Monitoring for Fiscal Year 2002.*

The reactor coolant water and other liquids discharged to the trench contained an estimated 300,000 kg of sodium dichromate plus other chemical wastes and a significant radiological inventory. An estimated 2,100 Ci of radionuclides were disposed to the trench (UNI-946, *Radiological Characterization of the Retired 100 Areas* and WHC-SD-EN-TI-239, *100-K Area Technical Baseline Report*).

The unconfined aquifer in the 100-K Area is situated in the Ringold Unit E facies of the Ringold Formation. The base of the unconfined aquifer is formed by Ringold Formation paleosols and overbank deposits. The Ringold Unit E facies in the 100-K Area may be more cemented and less eroded than in surrounding 100 Areas. This is evidenced by Coyote Rapids located upstream of the 100-K Area, which is made up of very resistant, well-cemented Ringold Unit E sediments. Additional hydrostratigraphic description is found in DOE/RL-96-84 and WHC-SD-EN-TI-155, *Geology of the 100-K Area, Hanford Site, South-Central Washington.*

Groundwater flow in the 100-K Area is predominantly to the northwest. Flow direction is affected by the elevation (stage) of the Columbia River, artificial mounding caused by operational practices, and hydrostratigraphy.

Groundwater flow generally is toward the Columbia River except from May through August when the elevation (stage) is higher because of increased upriver dam releases. These releases raise the stage of the river and may reverse the flow direction (increased bank storage). The releases are managed to balance summer irrigation demand and power (electricity) production, and to maintain safe reservoir elevations for fisheries management.

When the 100-K Reactors were in operation, the full length of the 116-K-2 trench was filled to capacity with reactor coolant water. A groundwater mound about 6 m higher than the natural water table was created which reversed the flow direction inland (southeast) and increased the flow rate to toward the river (northwest). Any mounding should have long since dissipated; however, some contaminants may have been retained in the vadose zone.

Hydrostratigraphy has a strong influence on flow rate in the 100-K Area. The hydraulic conductivities vary greatly from 200 m/day in local areas downgradient of the 116-K-2 Trench to 2 m/day in the injection well area. The range of hydraulic conductivities probably is a function of the extent that the Ringold Unit E sediments are cemented. Slug test results are found in BHI-00917.

The original 100-K pump-and-treat target area was oblong shaped, on the downstream side of the 116-K-2 Trench, extending the full length of the trench (Figure 3-10). The 100 μg/L chromium isopleth extended the full length of the trench. Six extraction wells were constructed to capture the entire plume.

The November 2002 100-K chromium plume map is shown in Figure 3-10. Three remaining areas are surrounded by 100 μg/L isopleths; in addition, the extraction well network now includes eight wells, including well 199-K-126, which was converted from a compliance well to an extraction well during CY 2002.

The pump-and-treat system has removed approximately 184 kg of chromium from the aquifer since startup in 1997. The mass of chromium still remaining in the aquifer is unknown. However, it also is significant that the size of the high concentration portion of the plume (>100 μg/L) is shrinking. This is evidence that the pump-and-treat system is working.

Chromium concentrations in inland monitoring well 699-78-62 have been characterized by chromium concentrations that have remained about 35 to 40 μg/L. This plume may have been pushed inland by mounding during operations.

3.5 QUALITY CONTROL RESULTS FOR 100-K MONITORING DATA

The QC results for the 100-K sampling included field testing or offsite laboratory testing for hexavalent chromium and total chromium. Additionally, offsite laboratory tests were run for strontium-90 and tritium.

The highlights of QC data for CY 2002 100-K Area sampling are summarized below. Tables listing complete QC results are found in Appendix F.

Type Quality Control Sample	Number of Pairs	Number of Pairs <20% RPD	Percent < 20% RPD
Replicate	10	10	100%
Field/offsite laboratory split (hexavalent chromium)	13	10	77%

Type Quality Control Sample	Number of Pairs	Number of Pairs <20% RPD	Percent < 20% RPD
Field/offsite laboratory splits (hexavalent chromium/total chromium)	7	6	86%
Offsite laboratory replicates (total chromium)	6	5	83%
Offsite laboratory replicates (strontium-90)	7	6	86%
Offsite laboratory replicates	5	5	100%

RPD = relative percent difference.

The EPA functional guideline for field-tested replicates is ±20 percent (EPA 1988). There are no functional guidelines for split results, but the results correlated well based on the percentage of RPDs less than 20 percent.

3.6 CONCLUSIONS

RAO #1: Protect aquatic receptors in the river bottom substrate from contaminants in groundwater entering the Columbia River. The RAO for compliance wells is 22 µg/L based on the 11 µg/L ambient water quality criterion in place at the time of the signing of the ROD.

Results:

- Approximately 445.7 million L of groundwater were treated during 2002 and 35.3 kg of hexavalent chromium were removed.
- Chromium concentrations decreased more than 20 percent in three extraction wells and two compliance wells. Chromium concentrations increased more than 20 percent only in extraction well 199-K-120A.
- Five pump-and-treat area wells had strontium-90 concentrations above the 8 pCi/L MCL. The maximum concentration was 39.5 pCi/L in monitoring well 199-K-21.
- Three pump-and-treat area wells had tritium concentrations above the 20,000 pCi/L MCL. The maximum concentration was 85,600 pCi/L in extraction well 199-K-120A, an increase of 206 percent over 2001.
- The area enclosed by the 100 µg/L isopleth has decreased in November 2002 compared to the 1995 baseline 100-K Area chromium plume. This decrease is a strong indication that the pump-and-treat system is working.
- The most downstream portion of the chromium plume appears to be outside hydraulic capture by the 2002 extraction well network. Compliance well 199-K-126 was made operational as an extraction well in January 2003 to capture this portion of the plume.

RAO #2: Protect human health by preventing exposure to contaminants in groundwater.

Result: The interim remedial action RODs establish a variety of institutional controls that must be implemented and maintained throughout the interim action period. These provisions include some of the following:

- Access control and visitor escorting requirements
- Signage providing visual identification and warning of hazardous or sensitive areas (new signs were placed along the river and at major road entrances at each reactor area)
- Excavation permit process to control all intrusive work (well drilling, soil excavation)
- Regulatory agency notification of any trespassing incidents.

The effectiveness of institutional controls established in each interim action ROD will be evaluated and summarized for their implementation and effectiveness annually as defined by DOE/RL-2001-41.

RAO #3: Provide information that will lead to a final remedy.

Results: The following information will be used in determining the effectiveness of ongoing operations in reaching a final remedy:

Treatment Cost: Treatment cost for the period was $2,436,900. At a yearly production rate of 445.7 million L and 35.3 kg of chromium removed, the treatment cost equates to about $0.005/L, or $69/g of chromium removed.

System Efficiency: Removal efficiency of the treatment system was approximately 95 percent.

Hydraulic Impact: A numerical model was used to estimate the effectiveness of the capture and containment of the pump-and-treat system. Based on numerical modeling, the 100-KR-4 System, with eight extraction wells operating at or near their designed flow rates, captures groundwater from the targeted area all along the length of the trench. This groundwater would otherwise discharge into the Columbia River. Because the extraction wells penetrate the aquifer, it is assumed that contamination throughout the full thickness of the unconfined aquifer is captured.

Effectiveness of Contaminant Removal in Aquifer: During this reporting period, approximately 445.7 million L of water were treated from the 100-KR-4 OU, which resulted in the removal of 35.3 kg of chromium. Since initiation of the system in October 1997, more than 1.69 billion L of water have been treated, resulting in the removal of approximately 184.1 kg of chromium from the 100-KR-4 aquifer.

Maintain Data: Pertinent data have been maintained in the HEIS database and in the Project Specific Database.

System Availability: Overall system availability for the reporting period was approximately 98.3 percent, which is the slightly higher than in CY 2001. System availability is a ratio of the actual time that the system is online to the total time available for operation. Downtime includes scheduled and unscheduled maintenance; system modifications; and outages associated with weather, power loss, and other acts of nature.

3.7 RECOMMENDATIONS

- Continue pump-and-treat operations. The recirculation cells should develop in more downgradient wells in 8 to 10 years based on modeling in the remedial design report. As these cells develop, the concentrations in extraction and compliance wells should drop significantly.
- Evaluate increasing the pumping rate in 199-K-120A to increase the gradient and flow rate through well 199-K-18, and establish how well 199-K-18 reacts to changes in aquifer conditions. This evaluation should be implemented after bringing on line replacement extraction well 199-K-129, and remaining system capacity is known.

Figure 3-1. 100-KR-4 Operable Unit Layout.

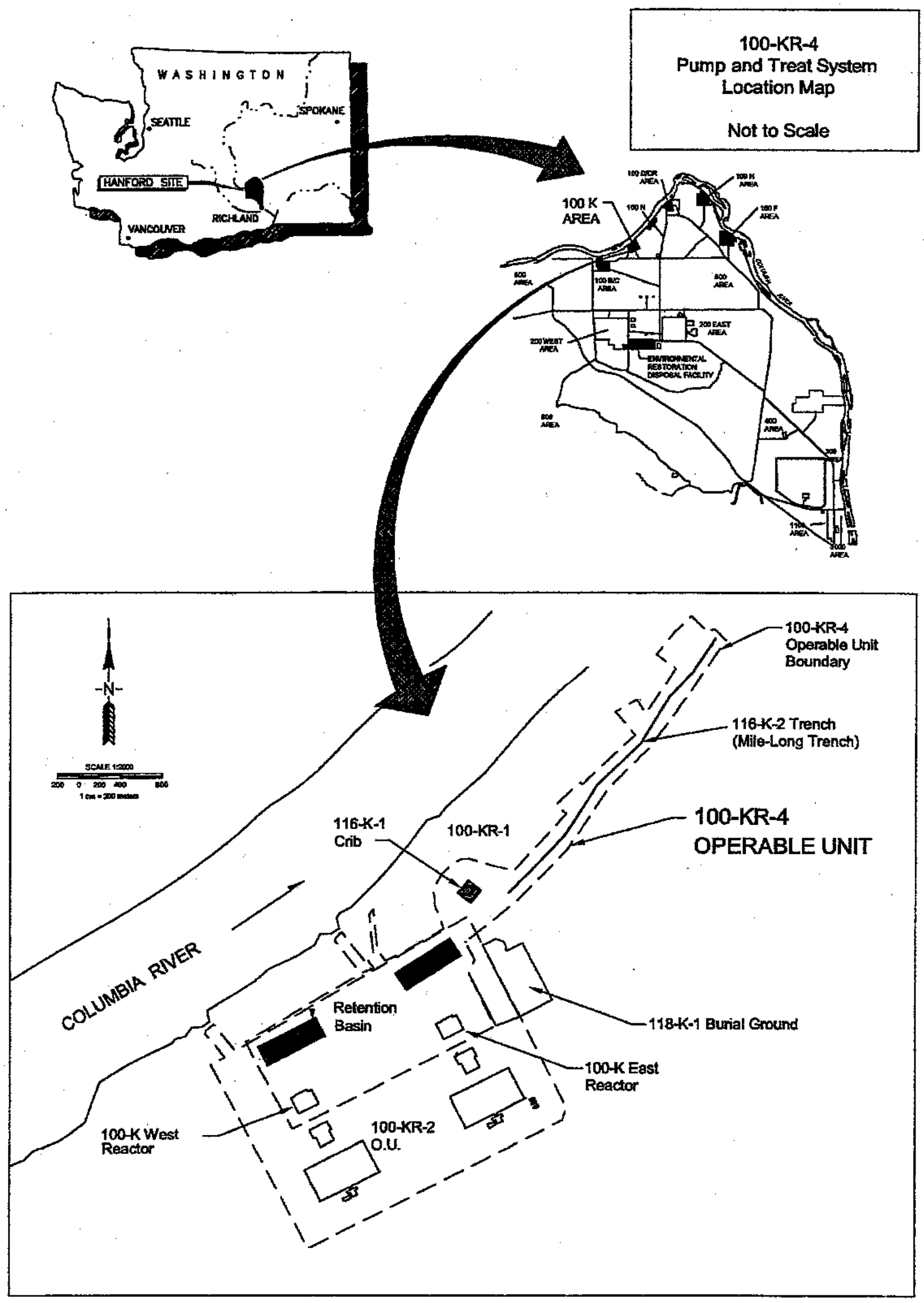


Figure 3-2. 100-KR-4 Operable Unit Wells and Aquifer Sampling Tubes.

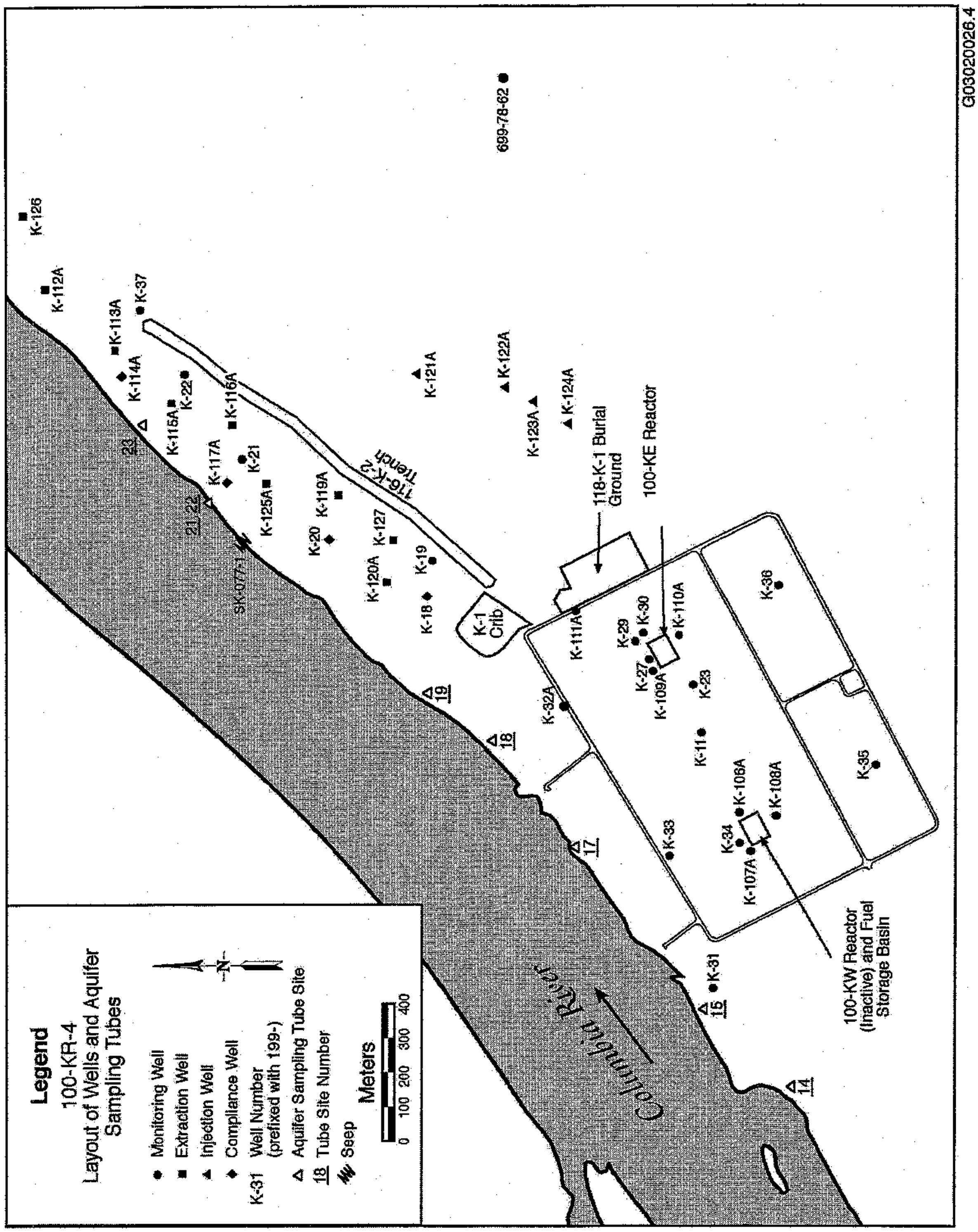
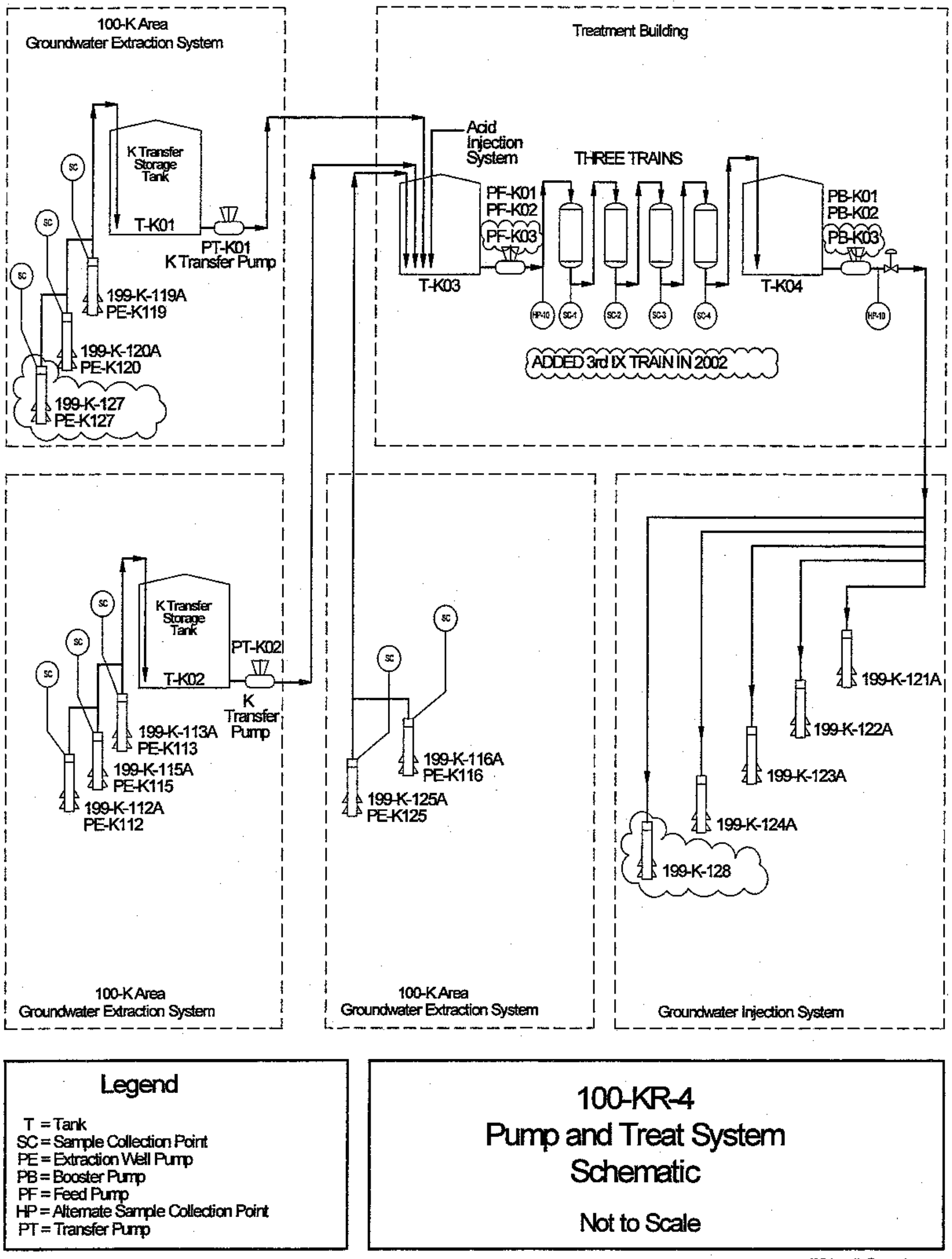


Figure 3-3. 100-KR-4 Operable Unit Pump-and-Treat System Schematic.



CLOUD AREA REPRESENTS CERCLA UPGRADES IN 2002

1 IX TRAIN ADDED IN 2002

Figure 3-4. 100-KR-4 Pump-and-Treat Trends of Average Removal Efficiencies.

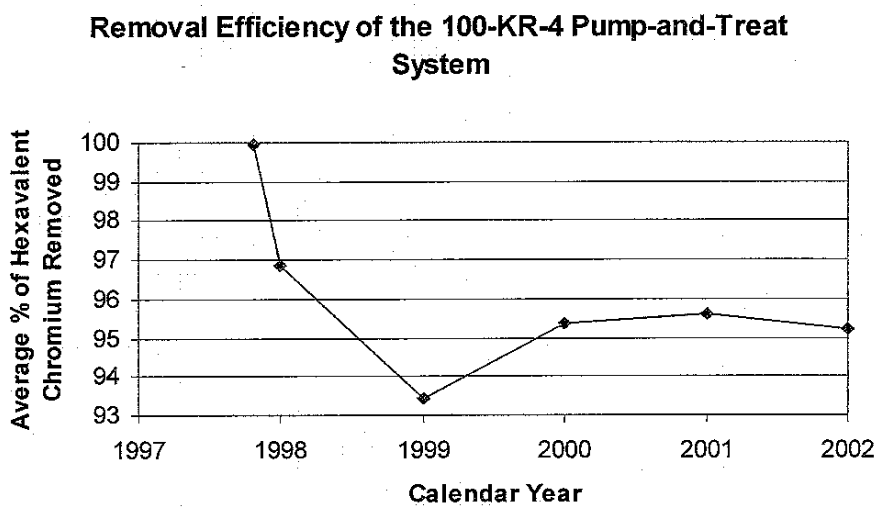
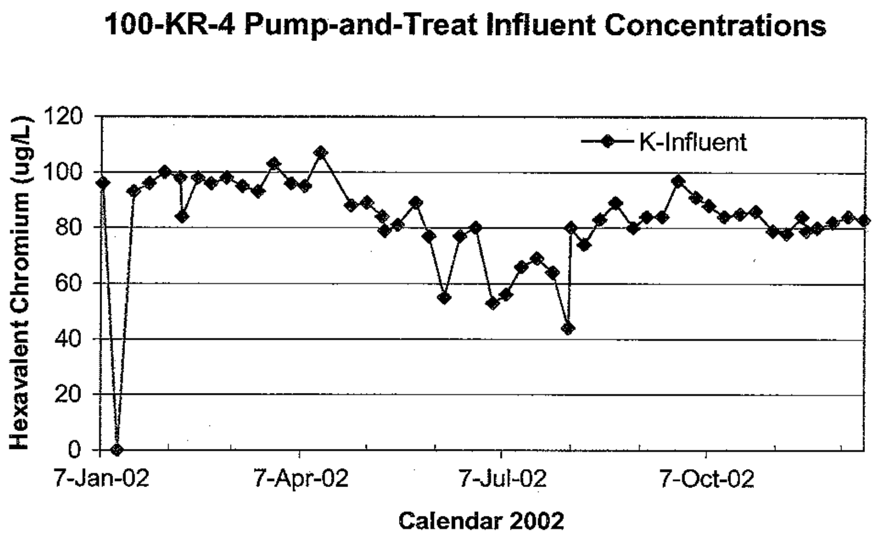


Figure 3-5. 100-KR-4 Pump-and-Treat Trends of Influent and Effluent Hexavalent Chromium Concentrations.



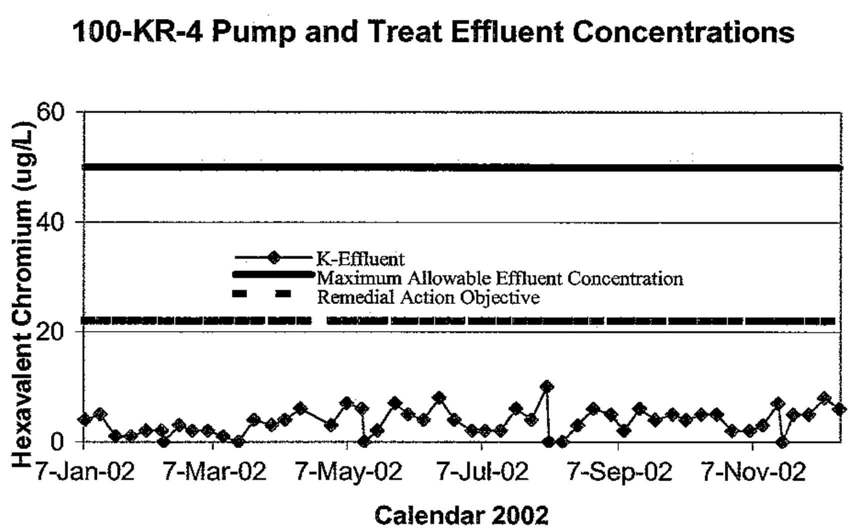
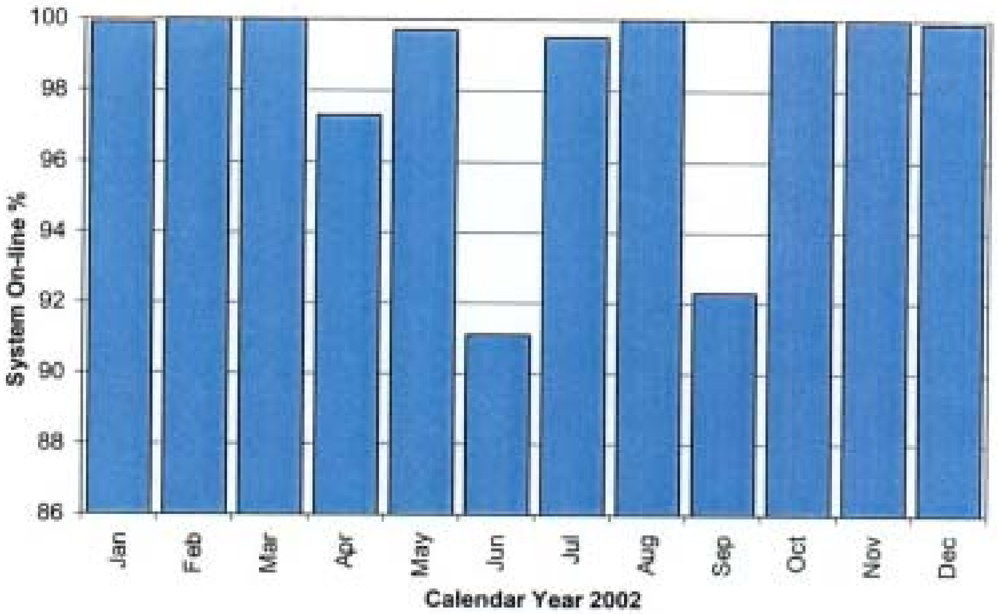


Figure 3-6. 100-KR-4 System Availability and On-line Percentages.



Significant outages include the following:

- January 31: Power outage shut down system at approx. 1630 hours.
- March 13: System shut down for 4 hours for electrical upgrade.
- March 27: System was shut down from approx. 0745 hours on 3/27/02 until approx. 1445 hours on 3/28/02 due to system upgrades.
- April 17: Shut down system at approx. 0730 hours for the rest of the reporting period for system upgrades. Restarted system at approx. 1000 hours on 4/25/02 after being down due to system upgrades.
- May 14: Shutdown A, B train, and ext. well K-127 to support subcontractors work. However, system shut down due to high tank levels after tanks became unbalanced.
- June 4: System down from 0830 to 1330 hours on 6/4/02 due to influent tank overflow.
- June 8: System shut down at 0147 hours on 6/8/02 for the rest of the reporting period due to high well level in injection well K-124 which shut down the booster pumps.
- June 10: Restarted system at approx. 0820 hours on 6/10/02 after being down due to high injection well level.
- July 30: System shut down due to loss of power to programmable logic controller from approx. 1100 hours to 1520 hours.
- August 10: Power outage caused booster pumps to shut down at 1430 hours
- September 28: System shutdown for 53 hours due to wire being chewed through by an animal which shorted the power supply.
- October 3: Power outage caused system to shut down for 15.5 hours.
- November 11: Power outage occurred at approx. 1630 hours in 100 Areas.

Figure 3-7. Estimated Steady-State Hydraulic Capture Zone Developed by 100-KR-4 Operable Unit Extraction Wells.

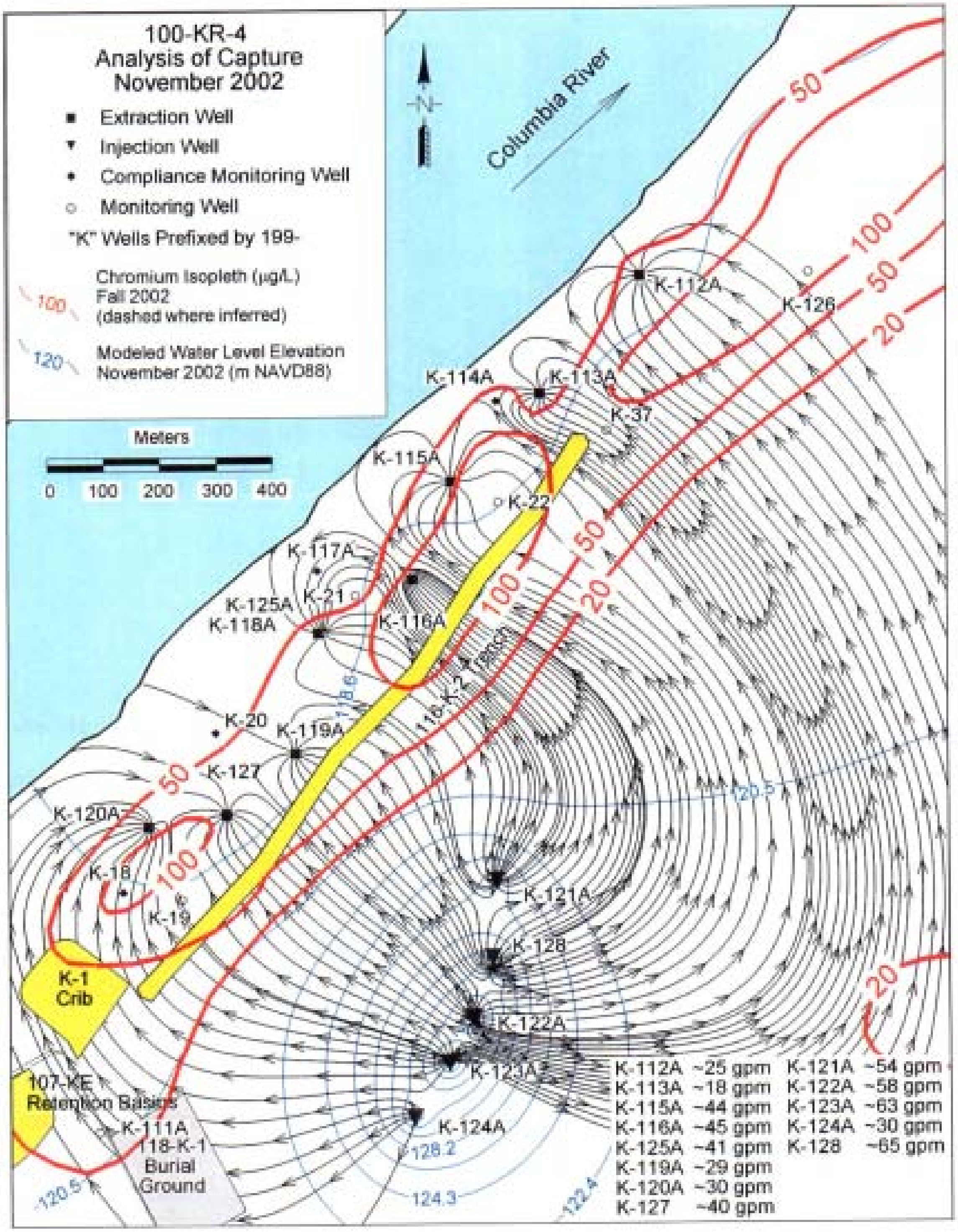


Figure 3-8. Evaluation of 100-KR-4 Hydraulic Capture Using Water Particle Flow Analysis.

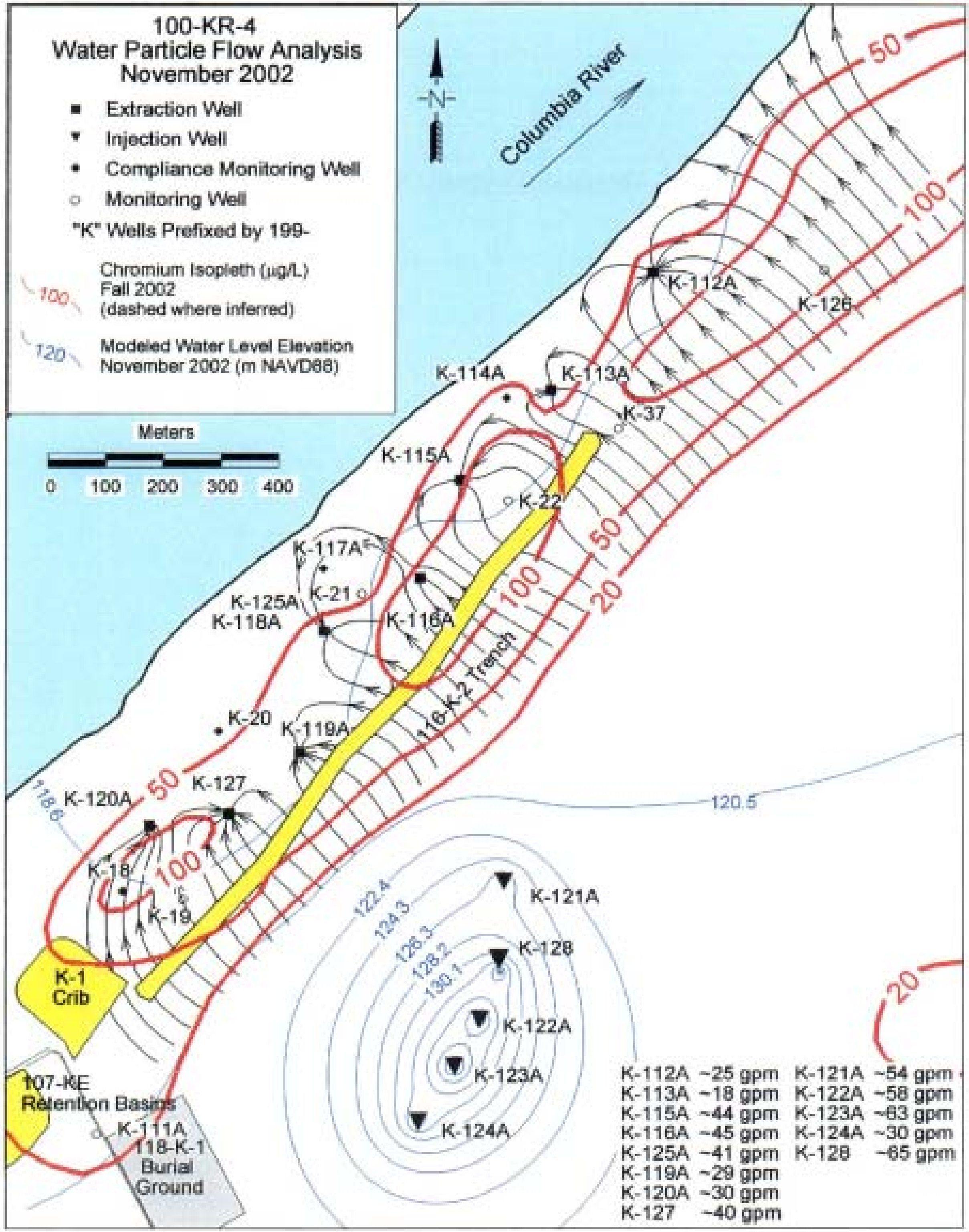


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Figure 3-9. 100-KR-4 Chromium Plume, Fall 2002.

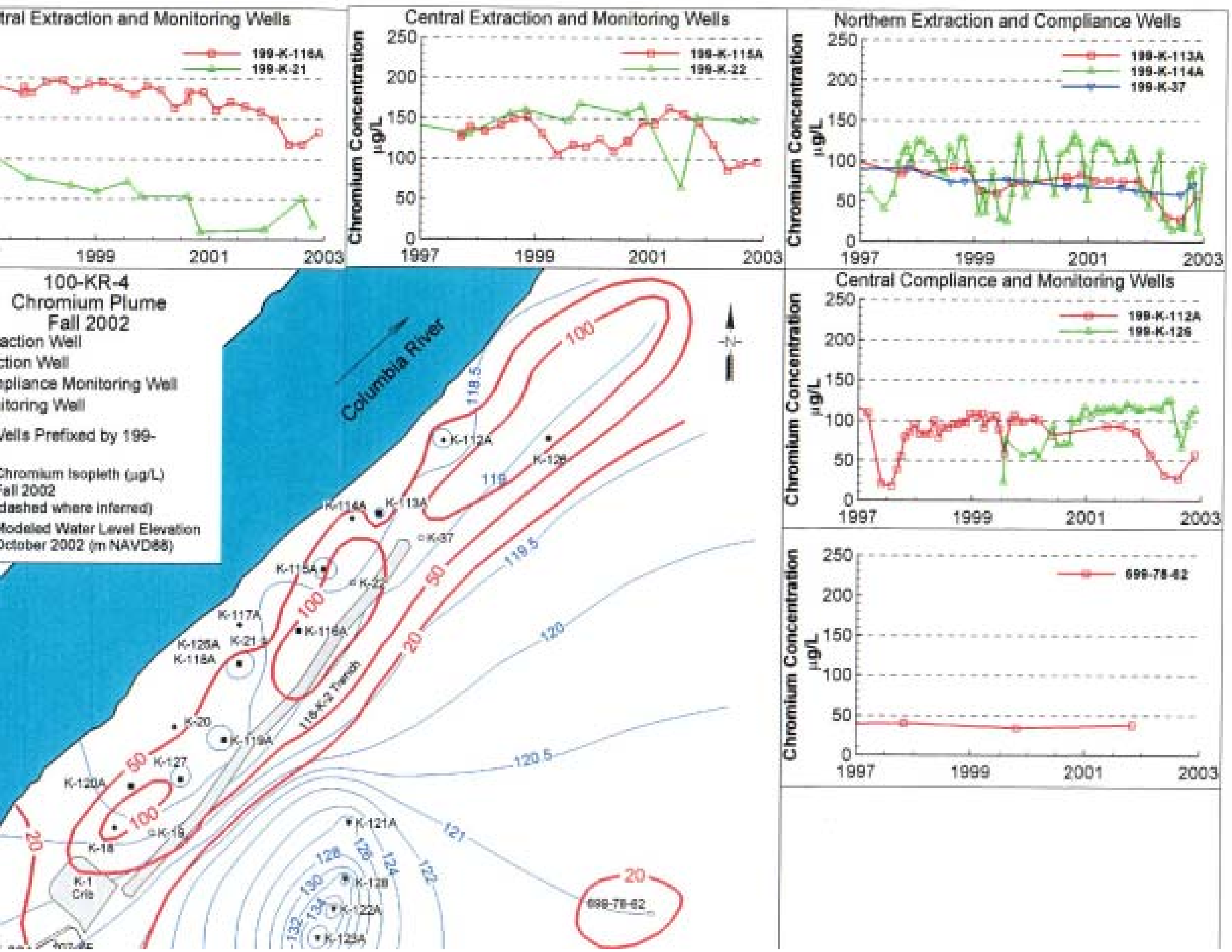

Figure 3-10. November 2002 100-K Chromium Plume Map.

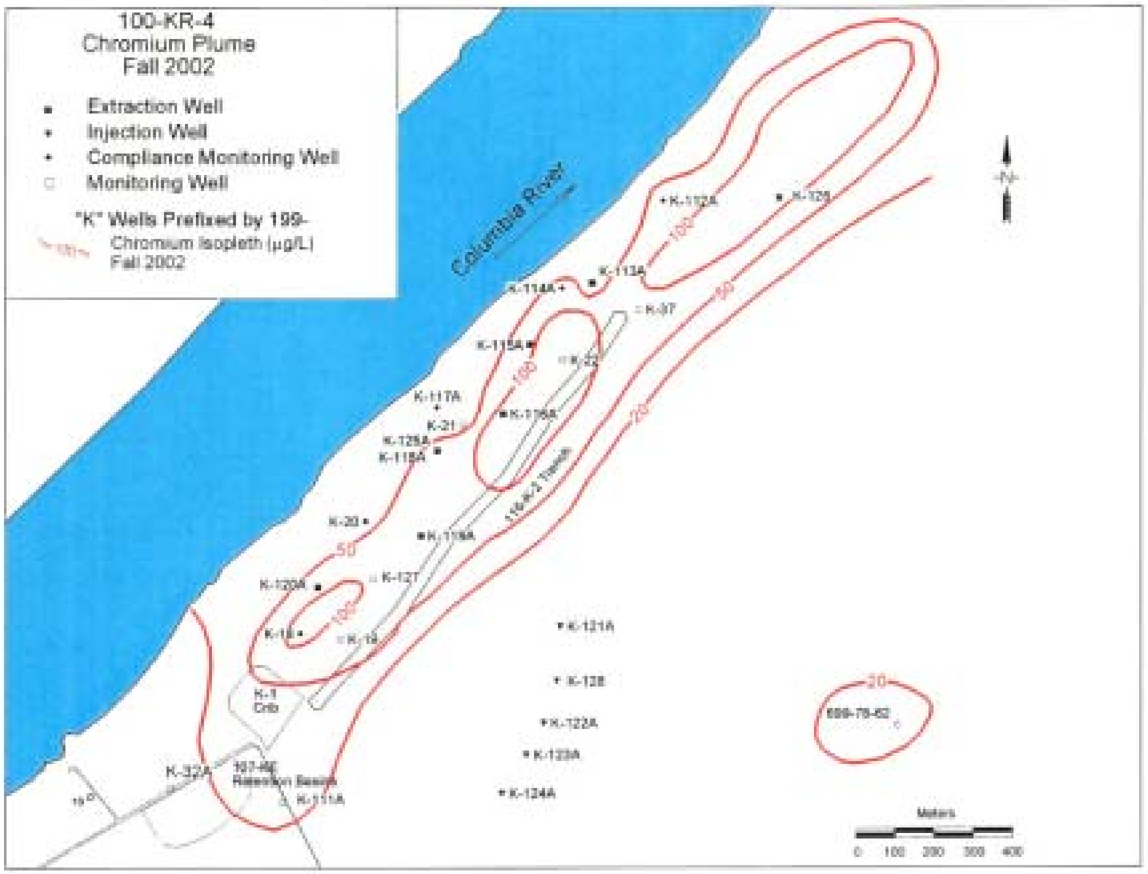

Table 3-1. 100-KR-4 Water-Level Data and Results of the Drawdown/Buildup Analysis Used to Develop and Calibrate Numerical Groundwater Flow Models.

Well	Model Analysis November 2002		Measured Water-Level Elevation, Nov 2002 (m NAVD88)[a]	Modeled Water-Level Elevation, Nov 2002 (m NAVD88)[a]	Drawdown/Buildup Analysis May 2002			
	Extraction Rate (L/min)	Injection Rate (L/min)			Extraction Rate (L/min)	Injection Rate (L/min)	Drawdown (m)	Buildup (m)
199-K-112A	95	---	116.45	116.51	76[b]	---	0.12	---
199-K-113A	69	---	116.53	115.82	76	---	0.53	---
199-K-115A	167	---	116.09	115.33	160	---	0.16	---
199-K-116A	169	---	118.34	118.56	168	---	0.72	---
199-K-125A	153	---	116.16	114.75	143	---	2.29	---
199-K-119A	110	---	116.64	116.18	111	---	2.43	---
199-K-127	150		116.80	116.34	148	---	1.72	
199-K-120A	112	---	118.26	118.16	113	---	0.81	---
199-K-121A	---	196	127.49	132.11	---	208	---	6.40
199-K-122A	---	212	125.73	145.83	---	213	---	3.14
199-K-123A	---	231	130.22	149.28	---	209	---	6.86
199-K-124A	---	111	129.80	141.71	---	26	---	1.76
199-K-128	---	235	125.48	142.31	---	144[b]	---	4.00
199-K-126	---	---	119.09	119.06	---	---	0.05	---
199-K-114A	---	---	118.67	118.34	---	---	0.63	---
199-K-37	---	---	118.86	118.85	---	---	0.33	---
199-K-22	---	---	118.33	118.53	---	---	0.64	---
199-K-117A	---	---	118.47	118.39	---	---	0.36	---
199-K-21	---	---	118.38	118.49	---	---	0.70	---
199-K-118A	---	---	117.17[Tape]	117.11	---	---	---	---
199-K-20	---	---	118.34	118.24	---	---	0.51	---
199-K-18	---	---	118.73	118.73	---	---	0.13	---
199-K-19	---	---	118.42	118.89	---	---	---	---

[a]NAVD88, 1983, *North American Vertical Datum of 1988*, National Geodetic Survey, Federal Geodetic Control Committee, Silver Springs, Maryland.

[b]Water-level measurement equipment not operable in May; data set collected in June - July.

[Tape] = Water-level obtained via tape measurement.

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4.0 100-NR-2 PUMP-AND-TREAT SYSTEM

The 100-NR-2 groundwater OU is located along the Columbia River between the 100-KR-4 OU and the 100-HR-3 OU (Figure 4-1). The 100-NR-2 OU represents the groundwater underlying the source OUs that are associated with the 100-N Reactor area. The 100-NR-2 pump-and-treat system is currently operating to retard movement of contaminated groundwater toward the Columbia River and, in the process, is removing small amounts of strontium-90. Figure 4-2 shows the general layout of the 100-NR-2 pump-and-treat system, wells, and facilities.

This section provides the annual performance report for the 100-NR-2 (N-Springs) pump-and-treat system required by the 100-NR-2 ROD (Ecology 1999, *Interim Remedial Action Record of Decision for the 100-NR-1 and 100-NR-2 Operable Units*). The purpose of this section is to evaluate treatment system and aquifer performance data collected during implementation of the expedited response action to assess compliance with the goals described in the ROD. Contaminant distributions and trends in the OU also are evaluated.

The following subsections summarize and evaluate the performance of the pump-and-treat system, the response of the aquifer in relation to these goals, and the OU contaminants. Section 4.1 provides a brief overview of concurrent source area remedial actions that are occurring within the OU. Section 4.2 focuses on the treatment system performance. Section 4.3 considers the aquifer response, including the baseline conditions, hydraulic effects, numerical modeling, contaminant changes during the pump-and-treat operations, and contamination distributions and trends throughout the OU. Section 4.4 presents the conceptual model. Section 4.5 discusses the QC of the analytical samples. Conclusions and recommendations are presented in Section 4.6. Cost information is presented separately in Section 5.0.

4.1 CONCURRENT ACTIVITIES

Concurrent activities that were conducted in CY 2002 for the 100-NR-2 OU include continued vadose zone remediation of the 1301-N Liquid Waste Disposal Facility (LWDF) and its associated waste sites and pipelines.

4.2 100-NR-2 TREATMENT SYSTEM PERFORMANCE

This section summarizes treatment system operations and sampling activities that occurred during CY 2002. This information includes system availability, mass of contaminants removed during operations, contaminant removal efficiencies, quantity and quality of extracted and disposed groundwater. Additional operational details are found in the associated section appendices.

System Operation

The treatment facility includes an ion-adsorption system that uses a natural zeolite (clinoptilolite) to remove strontium-90 from the groundwater. In 2002, no major operational changes were made that changed the operational performance of the pump-and-treat system. Figure 4-3 presents the current system process flow. A summary of operational parameters for CY 2002 and for total performance is as follows:

Total processed groundwater:	
Total since September 1995 startup (million L)	788.2
Total for CY 2002 (million L)	121.7
Mass of strontium-90 removed:	
Total since September 1995 startup (Ci)	1.3
Total for CY 2002 (Ci)	0.20
Average total flow rate of extraction wells for CY 2002 (L/min)	240
Average extraction well production range (L/min)	39 to 138
Average percent removal	90.0
Summary of 2002 operational parameters:	
Total time on line (hours)	8,323
Total possible run time (hours)	8,760
Scheduled down time (hours)	328
Unscheduled down time (hours)	109
Total system availability (%)	95
Scheduled system availability (%)	98.8

- The system availability of 98.8 percent for CY 2002 was comparable with the CY 2001 value of 98.3 percent. The system was on line 95 percent of the total hours during the year, which was higher than the 94 percent reported for CY 2001. Figure 4-4 details the system availability and on-line availability for CY 2002.

- The CY 2002 average influent activity for strontium-90 was 1914 pCi/L and the average effluent activity for strontium-90 of 327 pCi/L. These averages were slightly higher than the CY 2001 influent value of 1761 pCi/L and effluent value of 265 pCi/L. Trend plots of CY 2002 influent and effluent concentrations are presented in Figure 4-5.

Historical presentation of operational parameters, total system performance, and activities for influent and effluent can be found in Appendix B.

4.3 AQUIFER RESPONSE IN 100-NR-2

This section discusses the aquifer response in the 100-N Area in terms of hydraulic and contaminant change observed in the aquifer during CY 2002. Water level and groundwater chemistry measurements were collected at wells located in the 100-N Area as part of *Resource*

Conservation and Recovery Act of 1976, CERCLA, *Atomic Energy Act of 1954*, and interim remedial action performance monitoring.

Section 4.3.1 provides a summary of the measured hydraulic responses, Section 4.3.2 gives a summary discussion of the hydraulic capture exerted by the pump-and-treat system using numerical modeling and analysis, and Section 4.3.3 discusses the measured chemical responses to the pump-and-treat system.

4.3.1 Hydraulic Monitoring

The hydraulic impact of the pump-and-treat system on groundwater levels was monitored by in-well transducers and correlated to hourly river-stage data. An evaluation of these data indicates that the Columbia River flow rates returned to more normal levels during CY 2002 in comparison to the markedly lower flows of CY 2001.

Drawdown and buildup could not be measured and evaluated in the extraction and injection wells during CY 2002 because the pump-and-treat system was not shut down long enough to develop accurate trends. Table 4-1 summarizes measured water levels in the extraction, injection, and monitoring wells. Additional information summarizing the hydrogeologic condition and aquifer response in the 100-N Area is presented in Appendix C.

4.3.2 Numerical Modeling

The November 2002 modeled flow lines compared to the baseline predicted capture flow lines shown in DOE/RL-95-110, *N-Springs Expedited Response Action Performance Evaluation Report*, indicate that the pump-and-treat system performance is consistent with the results of the 1995 predictive model (Figure 4-6). The predictive model in DOE/RL-96-84 estimated that the pump-and-treat system would reduce the net flux of groundwater entering the Columbia River by 96 percent. The November 2002 modeled capture flow lines compared to the flow lines derived from average water levels measured in November-December 1995 are shown in Figure 4-7. This comparison is nearly identical to the comparison made in Figure 4-6 and supports the premise that modeled and measured flow lines are nearly the same. As with all previous evaluations, the effects associated with bank storage are not included in the evaluation.

A more detailed discussion of the model development is found in Appendix D.

4.3.3 Contaminant Monitoring

This section summarizes the 100-N Area groundwater monitoring results collected to support the interim remedial action and OU monitoring program during CY 2002.

The principal groundwater COCs in the 100-N Area are strontium-90, tritium, chromium, manganese, sulfate, and petroleum hydrocarbons.

4.3.3.1 Strontium-90 Monitoring Results

Strontium-90 was monitored in 3 extraction wells and 18 monitoring wells during CY 2002. Figure 4-8 displays the CY 2002 strontium-90 plume and associated historical trends. The outline of the strontium-90 plume has remained relatively unchanged since the startup of pump-and-treat operations.

The maximum strontium-90 concentration was found in well 199-N-67 where it was measured at 18,500 pCi/L (±4,200.5 pCi/L). This well is located downgradient of the 1301-N LWDF and has been characterized by the highest strontium-90 concentrations of any well in the network. The greatest increase in strontium-90 concentration was detected in well 199-N-2, which increased from 36.4 pCi/L (±5.4 pCi/L) to 662.5 pCi/L (±107 pCi/L). Well 199-N-2 is downgradient from well 199-N-67 where concentrations typically fluctuate.

4.3.3.2 Seeps

Seeps are sampled annually by the Sitewide Environmental Surveillance Project. The availability of seeps to sample has decreased because effluent has not been disposed to the LWDF since 1991 and lowered river state in drought years has reduced bank storage. However, seeps sampled in October 1991 along a section of shoreline approximately parallel to the 1301-N LWDF contained up to 1,800 pCi/L of strontium-90 (PNNL-13788). Whether the strontium-90 plume extends offshore into the river substrate (hyporheic zone) is not known because there are no river substrate sampling sites located off the 100-N Area shoreline.

4.3.3.3 Contaminants of Concern Monitoring Results

Other COCs in the 100-N Area include tritium, chromium, manganese, nitrate, sulfate, and petroleum hydrocarbons (EPA, Ecology, and DOE 1996, *Interim Remedial Action Record of Decision for the 100-NR-1 and 100-NR-2 Operable Units, Hanford Site, Benton County, Washington*). The results of the COC monitoring for 2002 are summarized as follows.

<u>Tritium</u>. Tritium was monitored in 22 wells during CY 2002. The highest tritium concentration was detected at 39,800 pCi/L (±4,000) in well 199-N-14, northwest of the 1301-N LWDF. Tritium concentrations were above the 20,000 pCi/L MCL in 9 wells sampled during CY 2002 compared to 12 wells sampled in CY 2001. Concentrations for tritium overall appear to be declining.

<u>Chromium</u>. Chromium is elevated only in well 199-N-80, completed in the first producing horizon in the confined aquifer. The CY 2002 concentration was 168 µg/L, consistent with 173 µg/L in CY 2001. The source of the elevated chromium may be deterioration of the stainless steel well casing. However, the next highest chromium concentration measured in CY 2002 in the 100-N Area was 14 µg/L in well 199-N-70.

<u>Manganese</u>. Manganese is elevated above the 50 µg/L MCL only in wells 199-N-16 and 199-N-18 where it was detected at 5180 µg/L. Well 199-N-18 is located adjacent to a diesel spill site, and the source of the elevated manganese may be reducing conditions caused by degradation of petroleum hydrocarbons. Well 199-N-16 is located downgradient from other

historic diesel spill sites; dissolved oxygen has been low in this well and the cause of the elevated manganese at this site also may be a reducing environment.

Nitrate. Average nitrate concentrations exceeded the 45 mg/L MCL in three monitoring wells during CY 2002, namely, 199-N-21, 199-N-3, and 199-N-67. Nitrate concentrations vary greatly in the 100-N Area. For example, average concentrations in well 199-N-2 were 108.3 mg/L for CY 2001 and declined to 25 mg/L in CY 2002. The source of the nitrate is unknown at this time, although nitrate is widespread throughout groundwater at the Hanford Site.

Sulfate. The maximum average CY 2002 sulfate concentration in 100-N Area monitoring wells was 200.5 mg/L in well 199-N-3; the likely source of this contamination was the 1324-NA facility. However, the average CY 2001 sulfate concentration in this well was 258.3 mg/L, above the 250 mg/L secondary drinking water standard.

Petroleum Hydrocarbons. Well 199-N-18 monitors the area of 100-N where a 300,000 L petroleum leak occurred during the 1960s. The total petroleum hydrocarbons (TPH)-diesel range declined from 6800 mg/L in September 2001 to 440 mg/L in September 2002 in this well. Similarly, the TPH-gasoline range declined from 4300 mg/L in September 2001 to 15 mg/L in 2002.

Monitoring well 199-N-96A, located downgradient from 199-N-18, was characterized by 1.5 mg/L of TPH-diesel range petroleum in September 2002. This is an increase from 0.05 mg/L (U) in September 2001. However, it does not appear that much of the TPH-diesel product has migrated from the 199-N-18 area to 199-N-96A, adjacent to the Columbia River. The results of TPH data have a high degree of uncertainty because of the spurious results that can be obtained when sampling a light, non-aqueous phase liquid.

Appendix E presents a historical summary of contaminant and co-contaminant monitoring results.

4.4 100-NR-2 CONCEPTUAL MODEL UPDATE

The conceptual model for strontium-90 contamination at the 100-N Area has been discussed in detail in DOE/RL-95-110. Groundwater chemistry data, water-level data, and operational information gathered since 1995 continue to support the original conceptual model. This update will briefly describe the 1995 conceptual model and provide information about source removal since then.

The main sources of strontium-90 contamination are the 1301-N LWDF, also known as the 116-N-1 facility, and the 1325-N LWDF, also known as the 116-N-3 facility. The 1301-N facility operated from 1964 to September 1985. The 1325-N facility operated from 1983 to 1991. These facilities received liquid wastes from the N Reactor that contained strontium-90, cobalt-60, cesium-137, plutonium, and tritium. Tritium was transported through the soil column with the liquid wastes, reaching groundwater and then moving with the groundwater. Cesium-137, cobalt-60, and plutonium were concentrated in the upper part of the soil column beneath the LWDFs. Strontium-90 was spread throughout the soil column and into the upper aquifer.

The upper aquifer in the 100-N Area is contained in the Ringold Unit E facies of the Ringold Formation. The base of the upper aquifer is the RUM. The Ringold Unit E sediments at the 100-N Area are composed of sandy gravel to sandy silt. Strontium-90 is adsorbed onto the aquifer solids and is in equilibrium with dissolved phase strontium-90. Dissolved phase strontium-90 removed by pump-and-treat operations will come back into equilibrium with the adsorbed phase when extraction ceases. It also should be noted that adsorbed strontium-90 on aquifer solids from past discharges occurs near the shoreline, based on core samples from well 199-N-95A (DOE/RL-93-80, *Limited Field Investigation Report for the 100-NR-1 Operable Unit*) and probably extends beneath the riverbed to some extent. This source is beyond the influence of the pump-and-treat capture zone. However, based on sediment core profiles from near the shoreline and near the 1301-N Trench, the expected concentrations of adsorbed strontium-90 should be an order of magnitude lower than in the more central portion of the capture zone in the vicinity of the 1301-N Trench. Additional details regarding the adsorption-desorption process can be found in DOE/RL-95-110.

The January 1995 strontium-90 inventory for the 1301-N and 1325-N LWDF soil column and underlying saturated zone was 1,866 Ci. In this total, 88 Ci were estimated adsorbed to soil particles in the saturated zone and 0.8 Ci were dissolved in groundwater (DOE/RL-95-110). The remaining inventory was assumed to be absorbed to soil particles in the vadose zone beneath the LWDFs (Figure 4-9).

As shown in Figure 4-9, the total strontium-90 inventory decreased to 1,547.5 Ci at the end of 2002, not including strontium-90 removed during source area excavation. During the 8 years between January 1995 and December 2002, the strontium-90 inventory was reduced 320.6 Ci, of which 319.3 Ci can be attributed to natural decay. The 100-NR-2 pump-and-treat system, which operated from September 1995 through December 2002, removed 1.3 Ci of dissolved strontium-90 from the saturated zone. Natural decay accounted for 15.2 Ci of strontium-90 during the same time. By way of comparison, about 7 Ci of strontium-90 passed through the Hanford Reach in 2002 due to washout of global fallout in the upper Columbia River drainage basin. The total estimated amount of strontium-90 released to the river during reactor operations was 46 Ci. Present-day annual flux to the river was computed to be on the order of 0.14 to 0.19 Ci/yr (DOE 2001, *Hanford 100-N Area Remediation Options Evaluation Summary Report*) (the Innovative Treatment and Remediation Demonstration [ITRD] report).

Figure 4-10 presents the historical comparison of the 1995 strontium-90 plume distribution in the 100-N Area based on sample results from 1994-1995 in about 30 wells (before the October 1995 start of pump-and-treat operations) and the September 2002 strontium-90 plume distribution. The difference between the two distributions largely is due to the number of data points used in contouring the plume.

4.5 THE INNOVATIVE TREATMENT AND REMEDIATION DEMONSTRATION PROCESS FOR THE 100-N-AREA

The Technical Advisory Group for the Innovative Treatment and Remediation Demonstration program reviewed the 100-N site hydrogeology, contaminant chemistry, and cultural resources from 1998 to 2001 in an attempt to identify alternative remediation technologies. The Technical Advisory Group selected 5 potential remediation scenarios out of 50 possibilities. These scenarios include the following:

- Monitored natural attenuation
- Clinoptilolite barrier with monitored natural attenuation on river side of barrier
- Clinoptilolite barrier with monitored natural attenuation and phytoremediation on the river site of the barrier
- Sheet pile/cryogenic impermeable barrier with monitored natural attenuation
- Sheet pile/cryogenic impermeable barrier with phytoremediation on the river side of the barrier and soil flushing on the inland side.

The ITRD report (DOE 2001) provided a general ranking of the alternatives with additional work needed, and none of the alternatives was selected as most suitable. The Technical Advisory Group also suggested that more cost evaluation was required. Other technologies that are being considered to control strontium-90 flux to the river include apatite sequestration and phytoremediation.

4.6 QUALITY CONTROL

The data used for QC included offsite laboratory testing for total chromium, manganese, strontium-90, tritium, sulfate, and nitrate.

The highlights of QC data for CY 2002 100-N Area sampling are summarized below. Tables listing complete QC results are found in Appendix F. All sample pairs are replicates.

Type Quality Control Sample	Number of Pairs	Number of Pairs <20% RPD	Percent <20% RPD
Total chromium	7	5	71%
Manganese	7	2	29%
Strontium-90	9	9	100%
Sulfate	9	9	100%
Tritium	7	7	100%
Nitrate	5	5	100%

RPD = relative percent difference.

There are no functional guidelines for offsite laboratory replicate results, but the results correlated well based on the percentage of RPD less than 20 percent. The high percentage of manganese replicates greater than 20 percent RPD probably is a result of the low concentrations; the highest manganese concentration was 4.8 µg/L.

4.7 CONCLUSIONS

RAO #1: Protect the Columbia River from adverse impacts from the 100-NR-2 groundwater so that designated beneficial uses of the Columbia River are maintained. Protect associated potential human and ecological receptors using the river from exposure to radiological and nonradiological contaminants present in the unconfined aquifer. Protect the unconfined aquifer by implementing remedial actions that reduce concentrations of radioactive and nonradioactive contaminants present in the unconfined aquifer.

Results:

- Pump-and-treat operations continue to reduce the hydraulic gradient between the Columbia River and the extraction wells; this activity decreases the volume of inland strontium-90 contaminated water entering the Columbia River.
- The capture area of the extraction as configured in the numerical modeling nearly matches the area predicted in DOE/RL-95-110. The pump-and-treat system is reducing net flux by approximately 96 percent based on a comparison of measured data and previous modeling results.
- The pump-and-treat system has removed minimal dissolved strontium-90 from the aquifer (1.3 Ci since startup). Natural decay and excavation of near-surface sources have been much more effective in removing strontium-90, and other radiological inventory, than pump-and-treat operations.

RAO #2: Obtain information to evaluate technologies for strontium-90 removal and evaluate ecological receptor impacts from contaminated groundwater (by October 2004).

Results:

- The current pump-and-treat system has removed approximately 1.3 Ci of dissolved strontium-90 from the 100-NR-2 groundwater since startup in 1995. The remaining inventory in the saturated zone includes approximately 0.5 to 0.8 Ci dissolved in groundwater and significant strontium-90 adsorbed to saturated sediments. The current technology has not been cost or time effective in removing strontium-90 from the aquifer.
- Remediation scenarios evaluated by the ITRD report (DOE 2001) include combinations of natural attenuation, phytoremediation, clinoptilolite permeable barrier, and sheetpile/cryogenic impermeable barrier.

RAO #3: Prevent destruction of sensitive wildlife habitat. Minimize disruption of cultural resources and wildlife habitat in general and prevent adverse impacts to cultural resources and threatened or endangered species.

Results: The interim remedial action RODs establish a variety of institutional controls that must be implemented and maintained throughout the interim action period. These provisions include some of the following:

- Access control and visitor escorting requirements
- Signage providing visual identification and warning of hazardous or sensitive areas (new signs were placed along the river and at major road entrances at each reactor area)
- Excavation permit process to control all intrusive work (well drilling, soil excavation)
- Regulatory agency notification of any trespassing incidents.

The effectiveness of institutional controls established in the interim action ROD for 100-NR-2 was evaluated and summarized for implementation and effectiveness in 2002. The *Institutional Controls Summary Report for the 100-NR-1 and 100-NR-2 Operable Units and the 100 Area Remaining Sites* (DOE 2002) presents the results for the current review. Institutional controls will be evaluated annually starting in 2003 as defined by DOE/RL-2001-41. In summary, institutional controls were maintained to prevent public access.

4.8 RECOMMENDATIONS

- Evaluate and select a more effective means of removing strontium-90 from 100-NR-2 groundwater.
- Conduct a literature review and evaluate existing data for the impacts of groundwater discharge to aquatic and riparian receptors.

Figure 4-1. 100-N Area Operable Unit Layout.

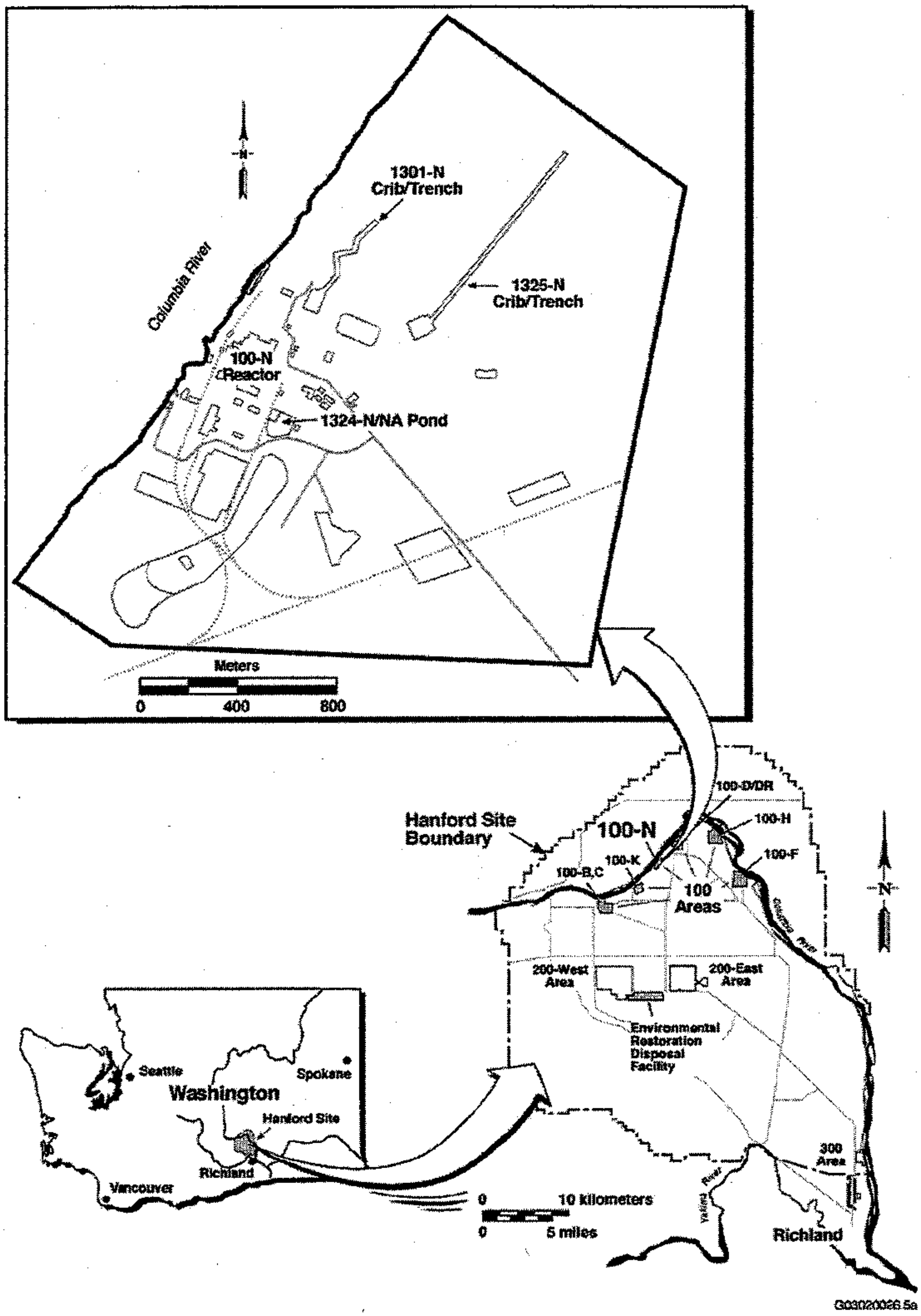


Figure 4-2. 100-NR-2 Operable Unit Wells and Seeps.

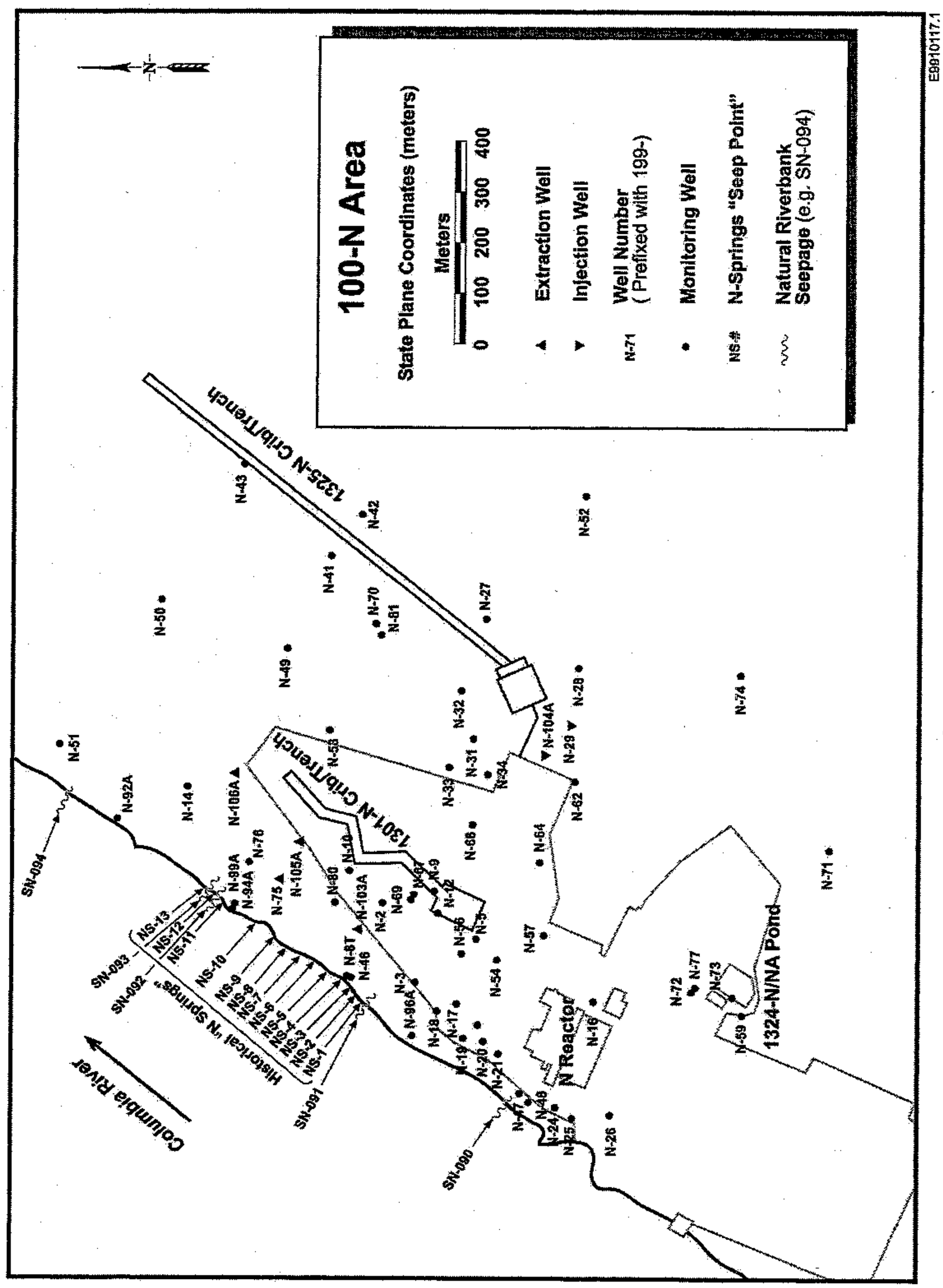


Figure 4-3. 100-NR-2 Pump-and-Treat System Schematic.

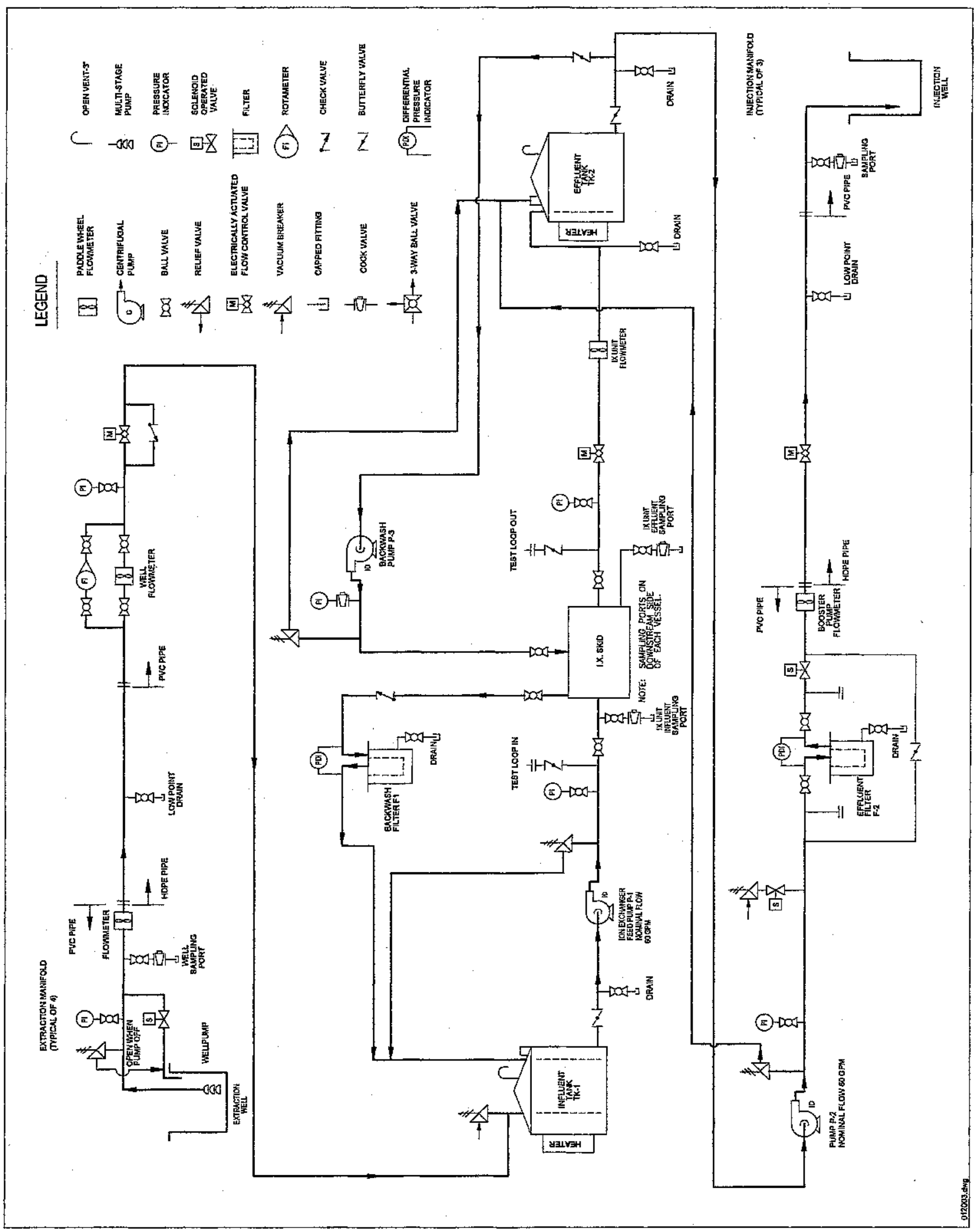
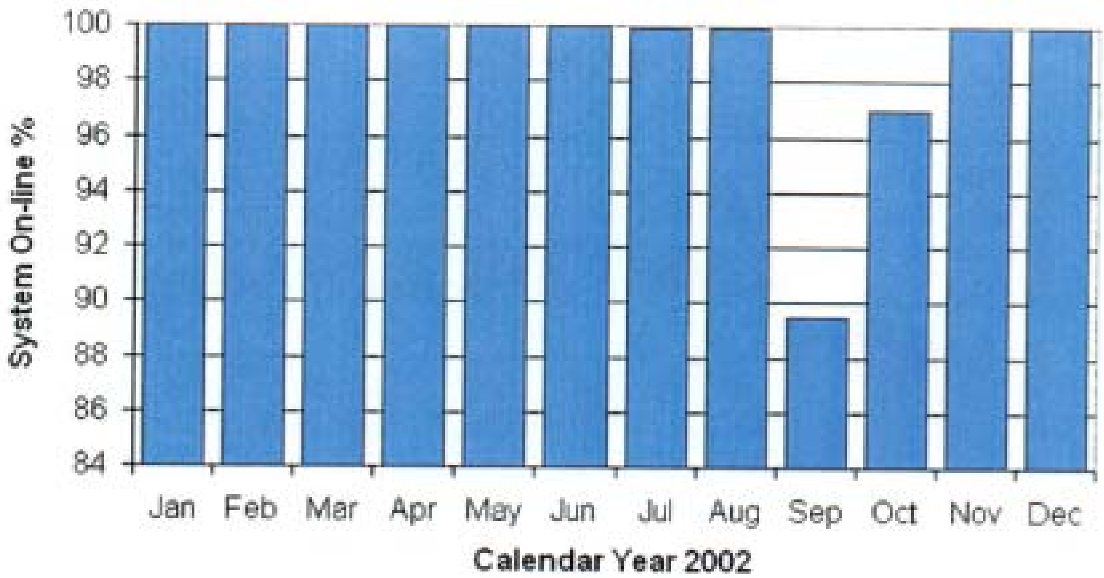


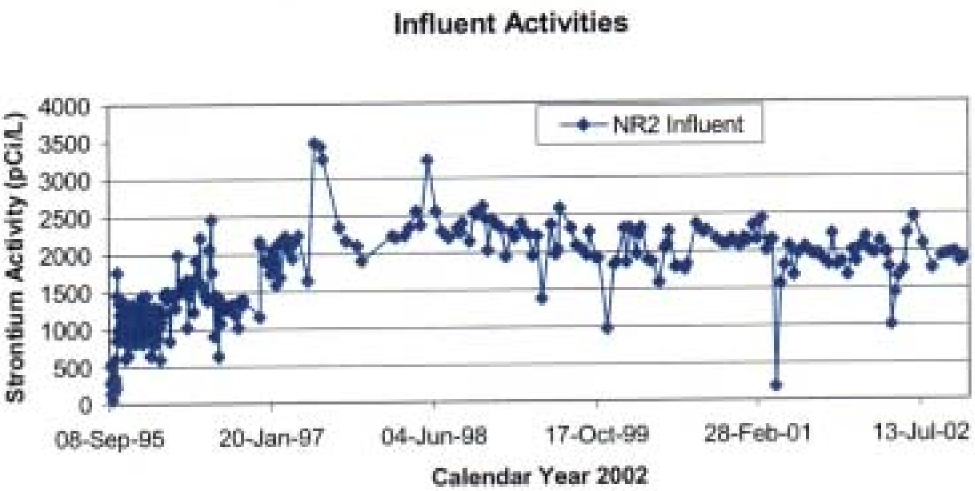
Figure 4-4. 100-NR-2 System Availability and On-Line Percentages.



Significant outages included the following:

- January 14: Clinoptilolite changeout on 1/14/02, system off-line for approx. 10 hours.
- January 31: Power outage shut down system for approx. 20 hours.
- January 14: Clinoptilolite changeout, system off-line for approx. 10 hours.
- February 12: Clinoptilolite change, shut down system for 10.5 hours to balance tanks.
- April 9: System was shut down for upgrades for approx. 20.5 hours.
- April 10: Clinoptilolite change, system shut down for approx. 12 hours.
- June 7: Clinoptilolite change, system shut down for approx. 26.5 hours.
- July 22: System shut down for approx. 13.5 hours due to power outage.
- July 23: Clinoptilolite change system shut down.
- July 25: System shut down due to low flow-through system.
- August: Clinoptilolite change, system shut down for approx. 6 hours.
- September: System was shut down on 9/17/02 due to booster pump problems and was restarted on 9/20/02.
- October 3: Power outage, system shut down for approx. 14 hours.
- October 15: Clinoptilolite change, system shut down for approx. 27 hours. Polyvinyl chloride piping was broken delaying the restart of the system for approx. 24 hours.
- November 4: Power outage occurred at approx. 1630 hours in the 100 Areas.
- December 11: Clinoptilolite change, system shut down for 9.5 hours.

Figure 4-5. 100-NR-2 Pump-and-Treat Trends of Influent and Effluent Strontium-90 Concentration.



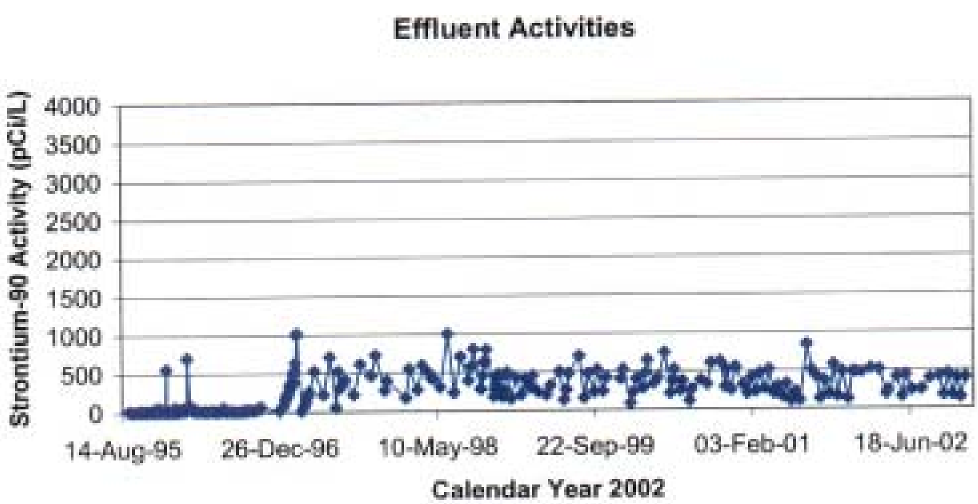


Figure 4-6. Comparison of November 2002 Modeled Capture Flow Lines (Operated at 227 L/min) to Predicted Capture Flow Lines (DOE/RL-95-110).

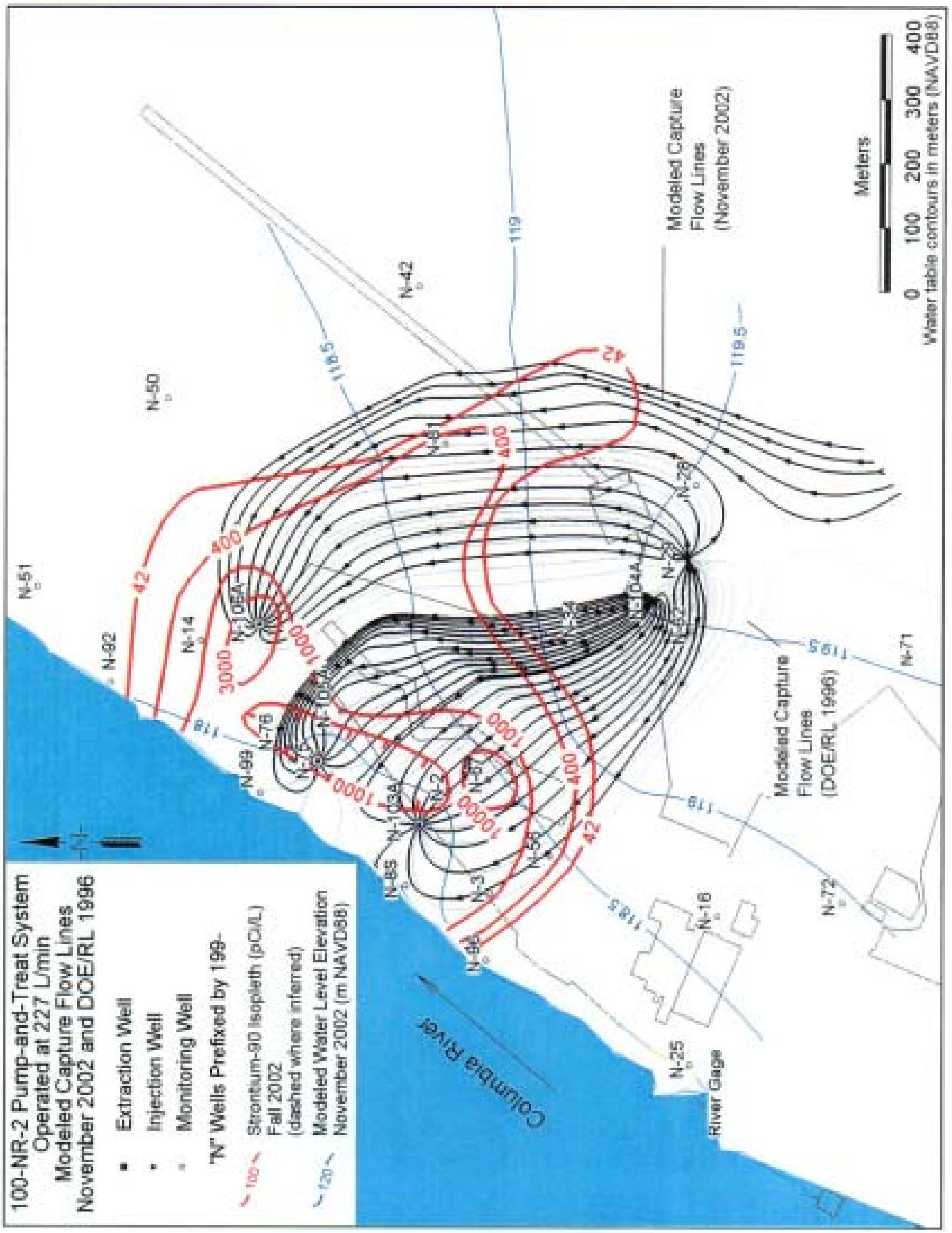


Figure 4-7. Comparison of November 2002 Modeled Capture Flow Lines to Flow Lines Based on Measured November-December 1995 Data.

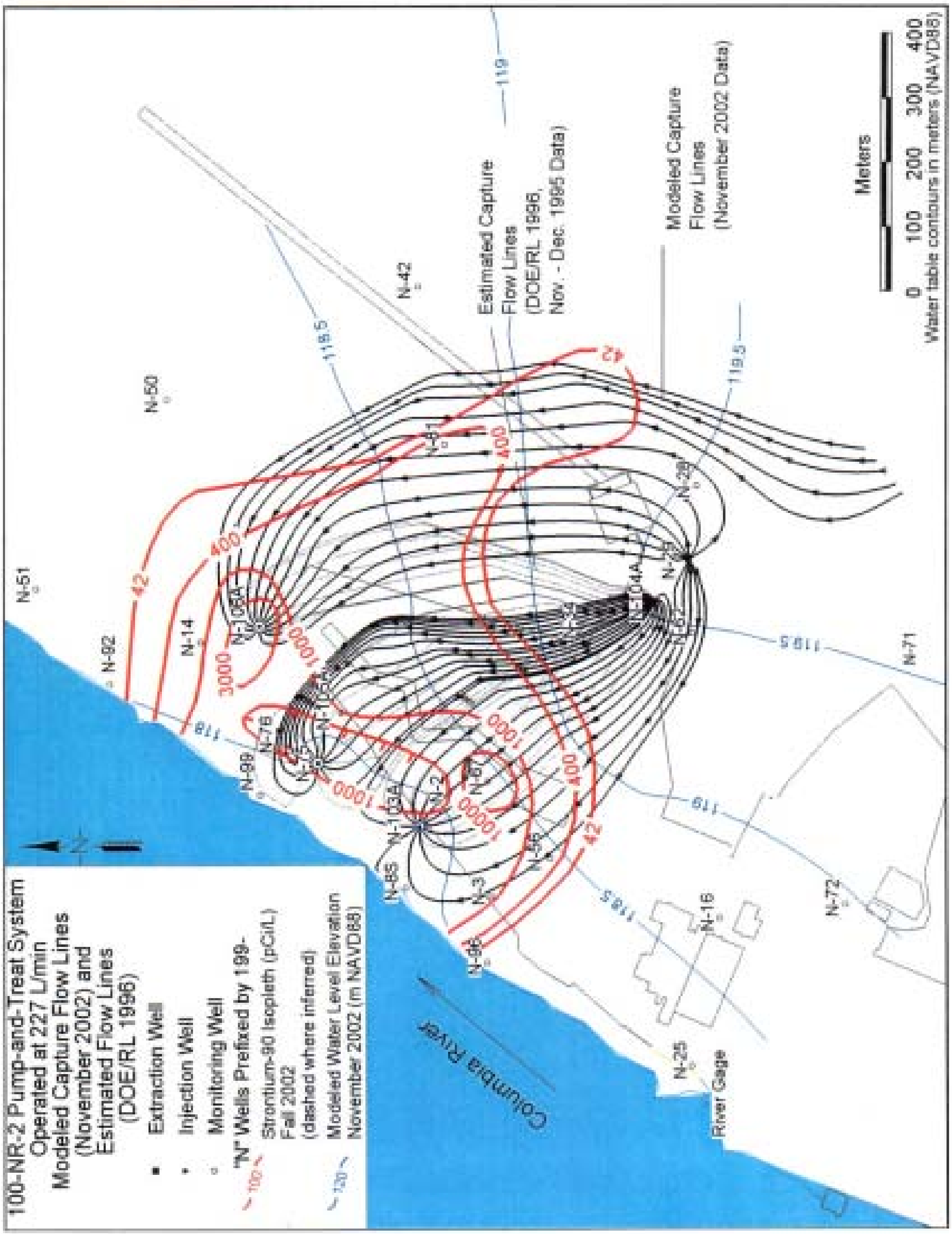


Figure 4-8. 100-NR-2 Strontium-90 Plume, November 2002.

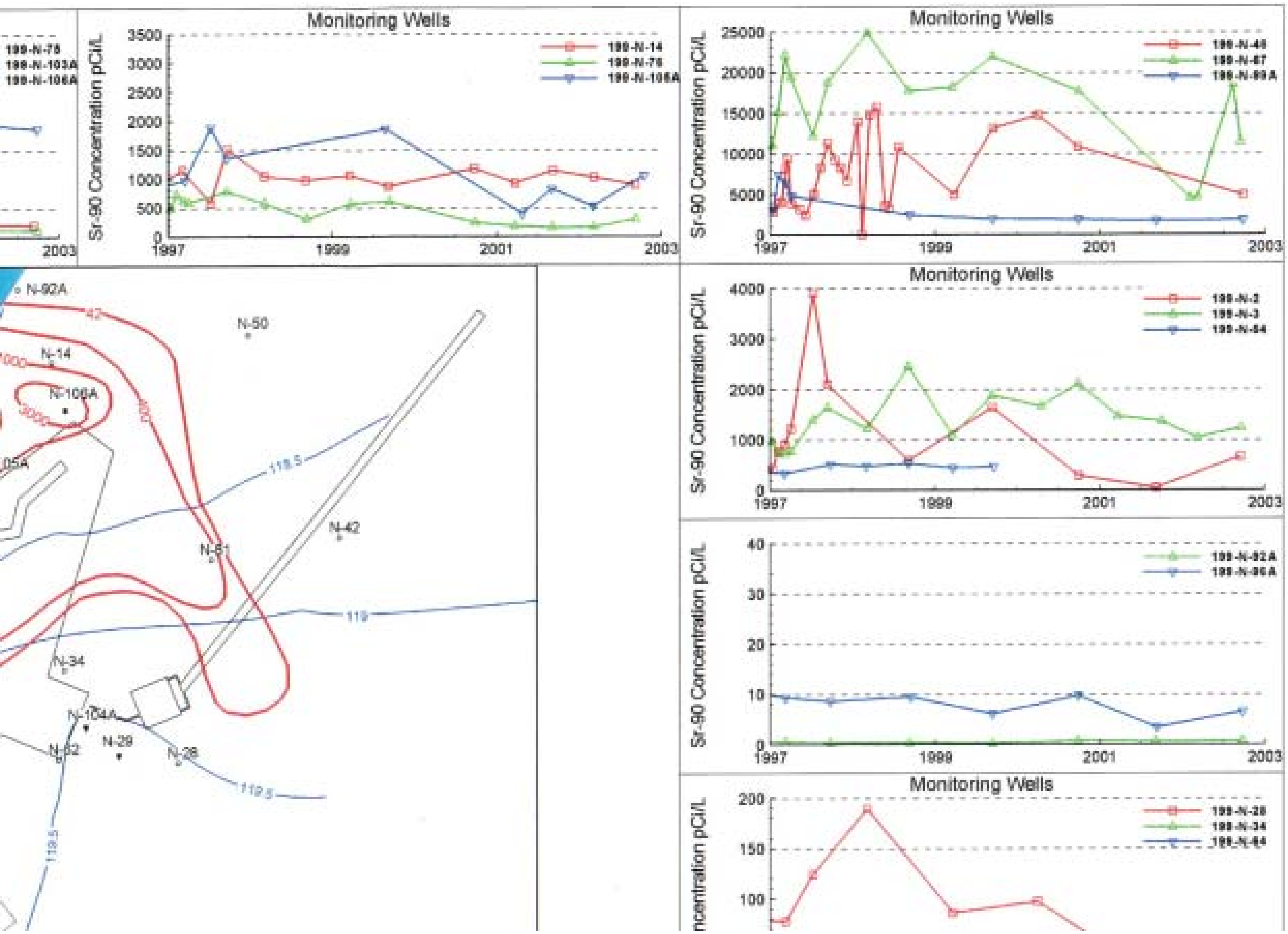
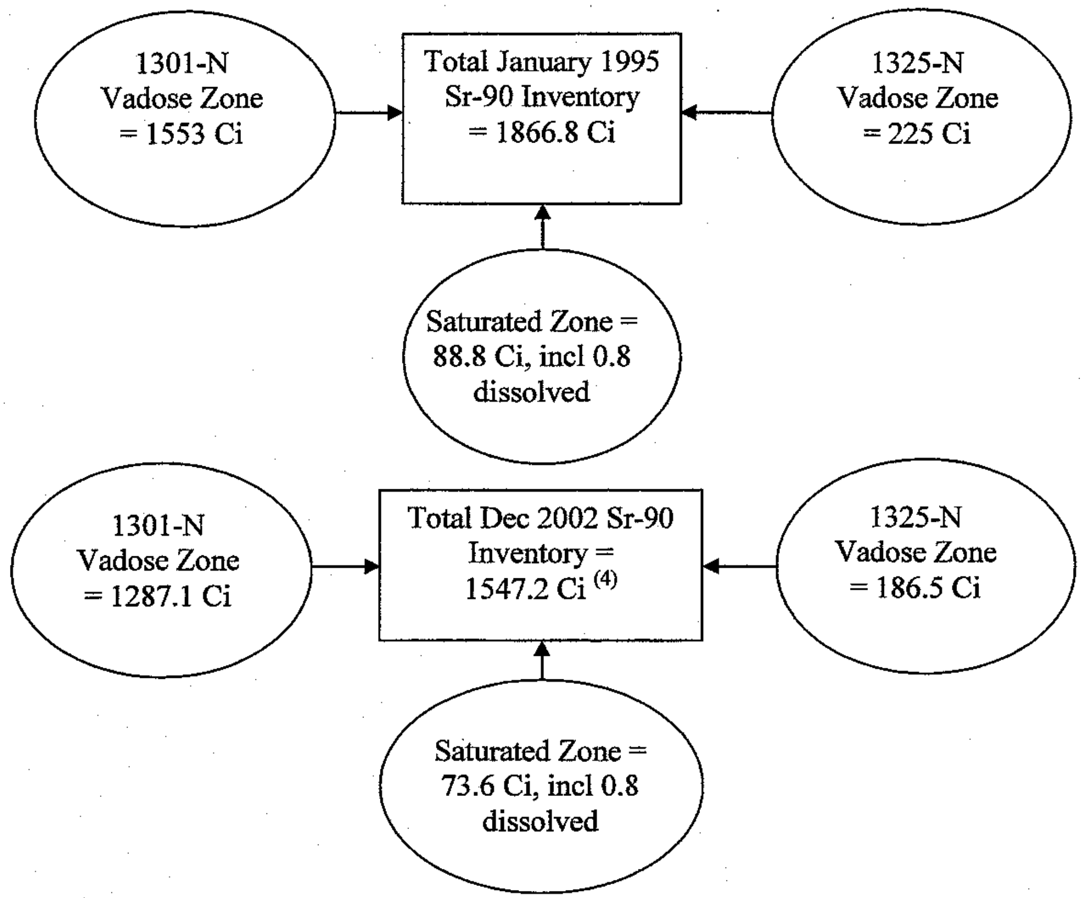


Figure 4-9. 100-NR-2 Site: Change in Strontium-90 Inventory from January 1995 to December 2002.



Notes:

1. Natural decay from January 1995 through December 2002 = 319.6 Ci.
2. Sr-90 removed by pump-and-treat operations since 1995 = 1.3 Ci.
3. January 1995 data from DOE/RL-95-110, 1996, *N-Springs Expedited Response Action Performance Evaluation Report*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.
4. Site remediation beneath 1301-N and 1325-N removed 15 ft of radiologically contaminated soil. However, number of curies Sr-90 removed is unknown. The excavated soil was only characterized by total radioactivity, not activity per individual isotope. Therefore, the total December 2002 Sr-90 inventory is less than 1547.2 Ci.

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Figure 4-10. 100-N 1997 and 2002 Chromium Plume Map.

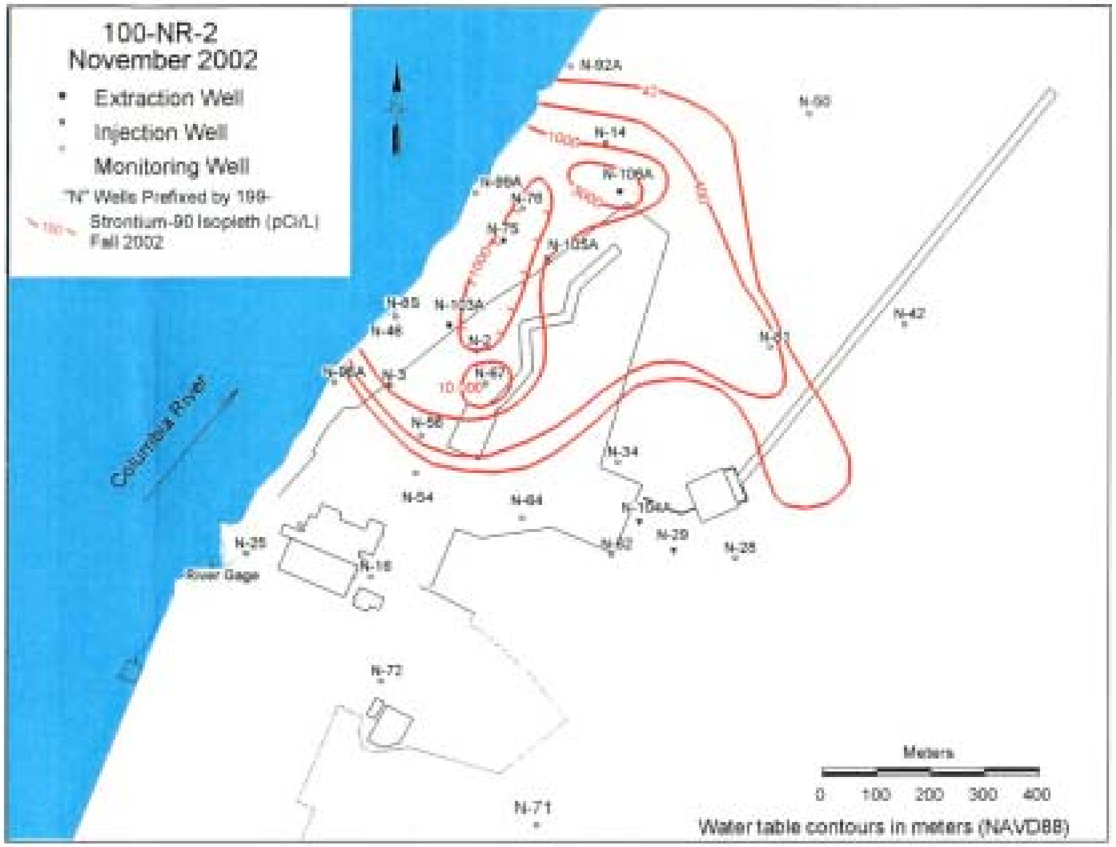

Table 4-1. 100-NR-2 Water-Level Data.

Well	Extraction Rate (L/min)	Injection Rate (L/min)	Measured Elevation Nov 2002 (m NAVD88*)	Modeled Elevation Nov 2002 (m NAVD88*)
199-N-75	42	---	114.14	117.42
199-N-103A	64	---	140.78	117.06
199-N-106A	141	---	116.89	117.98
199-N-105A	0	---	117.25	118.1
199-N-29	---	159	120.55	120.18
199-N-104A	---	88	122.20	119.81
199-N-2	---	---	118.20	118.13
199-N-3	---	---	118.29	118.13
199-N-8S	---	---	118.18	117.95
199-N-14	---	---	118.04	118.1
199-N-16	---	---	118.65	118.7
199-N-50	---	---	118.24	Fixed
199-N-76	---	---	117.95	118.02
199-N-92	---	---	118.03	118.01
199-N-99	---	---	117.91	117.95
199-N-34	---	---	119.32	119.16

*NAVD88, 1983, *North American Vertical Datum of 1988*, National Geodetic Survey, Federal Geodetic Control Committee, Silver Springs, Maryland.

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5.0 PUMP-AND-TREAT SYSTEM COST DATA

Actual costs for the 100-HR-3, 100-KR-4, and 100-NR-2 pump-and-treat systems were recorded in the Fluor Hanford, Inc., code of accounts database. Cost accruals are recorded, sorted by activity, and summed in the database. The data then can be used to determine the actual capital and labor costs associated with a specific activity during a given period of time. These data have been used to estimate actual project costs (burdened) and projected future costs (based on actual costs to date). Specific activities are briefly described below:

- **Design**: Includes design activities to construct the pump-and-treat systems and designs for major system upgrades and modifications.
- **Capital construction**: Includes oversight labor and subcontractor fees for capital equipment, initial construction, construction of new wells, redevelopment of existing wells, and modifications to the pump-and-treat system.
- **Project support**: Includes project coordination-related activities and technical consultation as required during the course of the facility design, construction, acceptance testing, and operation.
- **Operations and maintenance**: Represents facility supplies, labor, and craft supervision costs associated with operating the facility. It also includes costs associated with routine field screening and engineering support as required during the course of the pump-and-treat operation and periodic maintenance.
- **Performance monitoring**: Includes system and groundwater sampling and sample analysis as required in accordance with the 100-HR-3 and 100-KR-4 interim action work plan (DOE/RL-96-84).
- **Waste management**: This is the cost for the management of spent resin at 100-HR-3 and 100-KR-4 and spent clinoptilolite in accordance with the applicable laws for suspect hazardous, toxic, and regulated wastes. It includes waste designation sampling and analysis. Also included are resin regeneration costs.

Costs are burdened and are based on actual operating costs incurred during the reporting period.

5.1 100-HR-3 PUMP-AND-TREAT SYSTEM COSTS

The cost breakdown for the 100-HR-3 pump-and-treat system is shown in Figure 5-1. Total costs by percent of the total in the pie charts indicate that the majority of costs in decreasing order of magnitude are charged to operations and maintenance, treatment system capital construction, and waste management. The increase in treatment system capital construction costs for CY 2002 is associated with the system enhancements and improvements for the CERCLA 5-year review. Additional waste management costs in CY 2002 are a result of the purchase of new resin for the new process train constructed for the CERCLA 5-year review.

Increased operational and maintenance costs are associated with the added support required to implement the activities described above. Based on the CY 2002 costs ($2,735,200) and yearly production rate of 350.5 million L and 32.2 kg of hexavalent chromium removed, the annual treatment costs equate to $0.008/L or $85/g of hexavalent chromium removed. As shown in the chart at the bottom of Figure 5-1, treatment costs are slightly higher in comparison to CY 2000 and CY 2001 costs.

5.2 100-KR-4 PUMP-AND-TREAT SYSTEM COSTS

The cost breakdown for the 100-KR-4 pump-and-treat system is shown in Figure 5-2. Total costs by percent of the total in the pie charts indicate that the majority of costs are charged in decreasing order of magnitude to treatment system capital construction, operations and maintenance, and waste management. Compared to CY 2001, the increase in treatment system capital construction costs are associated with the system enhancements and improvements associated with the CERCLA 5-year review. Additional operations and maintenance costs for CY 2002 are associated with the added support required to implement the system upgrades for the CERCLA 5-year review. Based on the CY 2002 costs ($2,436,900) and yearly production rate of 445.7 million L and 35.3 kg of hexavalent chromium removed, the annual treatment costs equate to $0.005/L or $69/g of hexavalent chromium removed. As shown in the chart at the bottom of Figure 5-2, treatment costs are slightly higher in comparison to CY 2000 and CY 2001 costs.

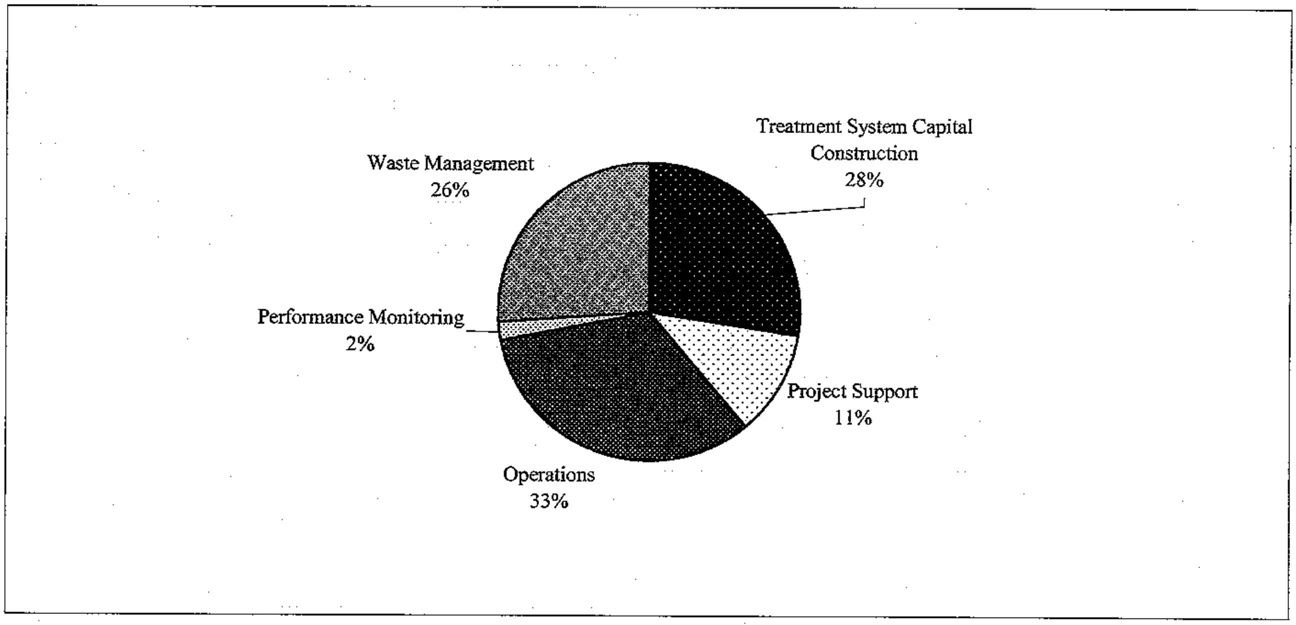
5.3 100-NR-2 PUMP-AND-TREAT SYSTEM COSTS

The cost breakdown for the 100-NR-2 pump-and-treat system is shown in Figure 5-3. Total costs by percent of the total in the pie charts indicate that the majority of costs are charged to operations and maintenance. Based on the CY 2002 costs ($1,023,600) and yearly production rate of 121.7 million L and 0.20 Ci of strontium-90 removed, the annual treatment costs equate to $0.008/L or $5,118,000/Ci of strontium-90 removed. As shown in the chart at the bottom of Figure 5-3, treatment costs are slightly lower in comparison to CY 2001 costs.

Figure 5-1. Cost Breakdown for 100-HR-3 Pump-and-Treat Construction and Operations.

	Actual Costs X 1000							
Description	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
Design	$ 872.1	$ 2,040.0	$ --	$ --	$ --	$ --	$ 97.7	$ 15.4
Treatment System Capital Construction	$ --	$ 164.0	$ --	$ --	$ --	$ 57.7	$ (36.1)	$ 750.3
Project Support	$ --	$ --	$ 741.0	$ 264.9	$ 265.3	$ 276.7	$ 225.8	$ 309.3
Operations & Maintenance	$ 1,258.8	$ 948.0	$ 3,437.0	$ 1,533.3	$ 1,650.8	$ 799.1	$ 739.2	$ 900.5
Performance Monitoring	$ --	$ --	$ 259.0	$ 0.4	$ --	$ 173.7	$ 219.9	$ 50.9
Waste Management	$ --	$ --	$ --	$ --	$ --	$ 895.3	$ 424.9	$ 708.8
Totals	$ 2,130.9	$ 3,152.0	$ 4,437.0	$ 1,798.6	$ 1,916.1	$ 2,202.5	$*1,671.4	$ 2,735.2

NOTES:
- = not available.
*= 2001 costs corrected for Project Support and Waste Management. Initial expense calculations for 2001 were not properly categorized.



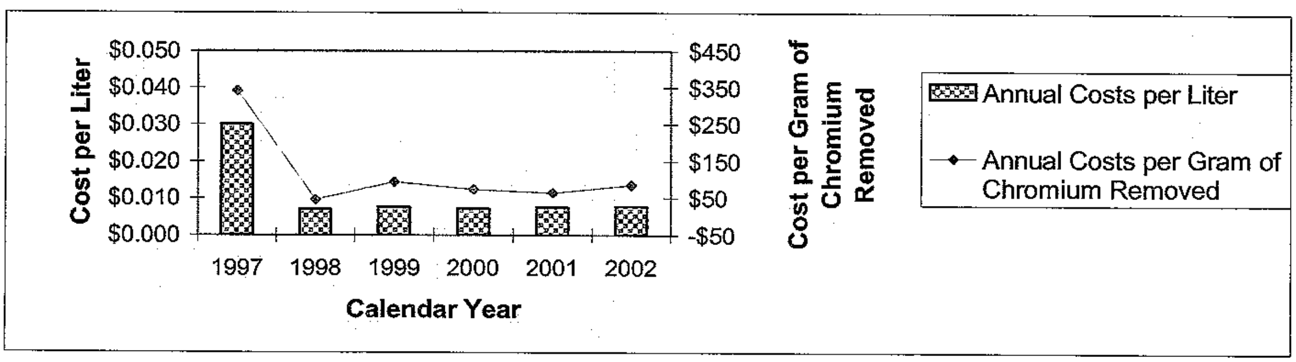
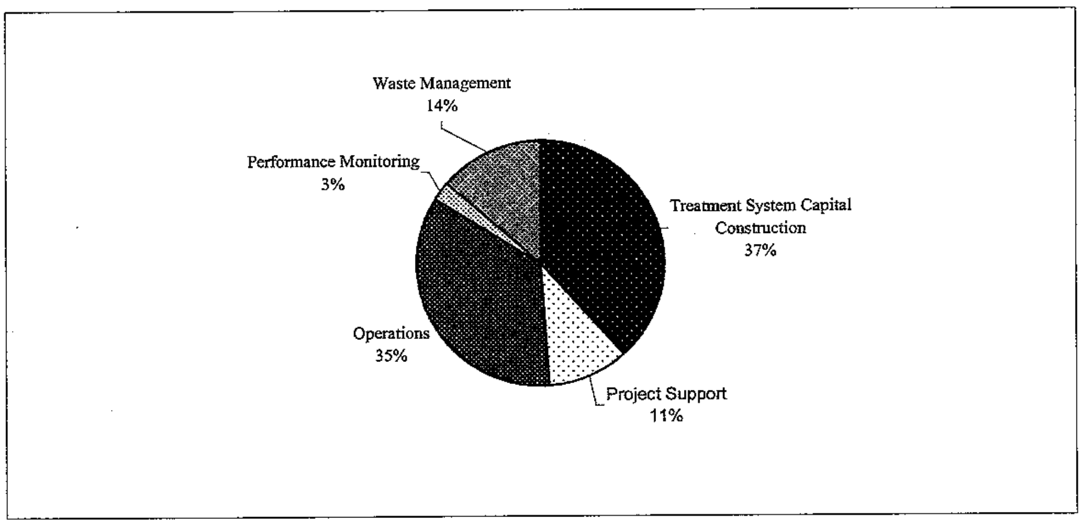


Figure 5-2. Cost Breakdown for 100-KR-4 Pump-and-Treat Construction and Operations.

	Actual Costs X 1000							
Description	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
Design	$ 479.5	$ 1,060.0	$ 163.0	$ 85.4	$ 0.2	$ --	$ 96.5	$ 6.8
Treatment System Capital Construction	$ --	$ 81.0	$ --	$ --	$ --	$ 109.1	$ (0.1)	$ 928.66
Project Support	$ --	$ --	$ 327.0	$ 208.4	$ 157.2	$ 143.0	$ 188.2	$ 257.8
Operations & Maintenance	$ --	$ 869.0	$ 2,525.0	$ 1,028.9	$ 717.4	$ 538.0	$ 578.6	$ 848.95
Performance Monitoring	$ --	$ --	$ 382.0	$ 1.4	$ --	$ 111.2	$ 122.6	$ 61.2
Waste Management	$ --	$ --	$ --	$ --	$ --	$ 481.8	$ 367.5	$ 333.5
Totals	$ 479.5	$ 2,010.0	$ 3,397.0	$ 1,324.1	$ 874.8	$ 1,383.1	$ *1,353.3	$ 2,436.9

NOTES:
- = not available.
*= 2001 costs corrected for Project Support and Waste Management. Initial expense calculations for 2001 were not properly categorized.



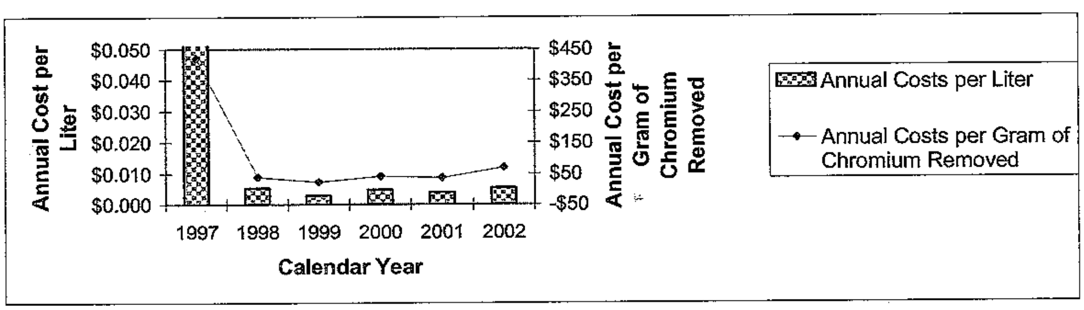
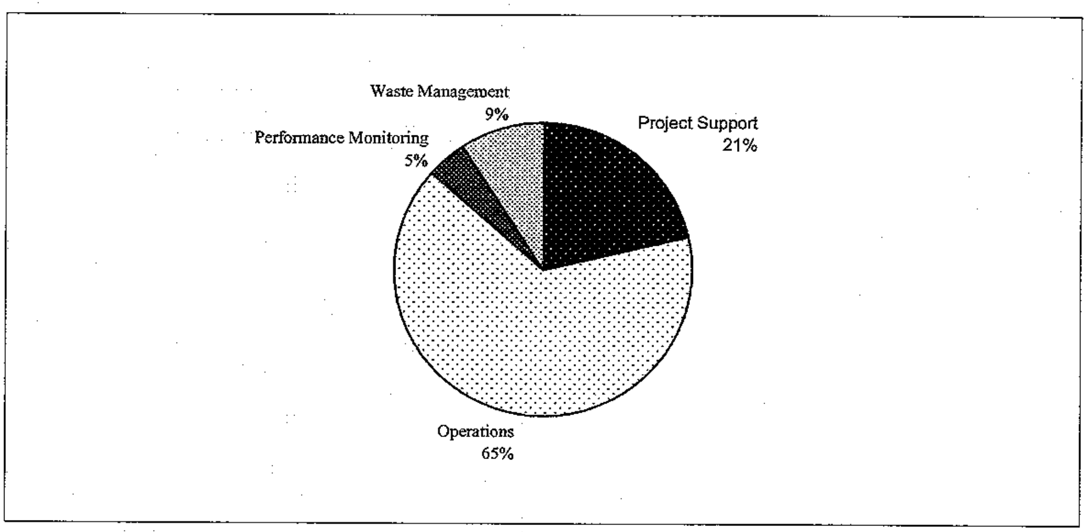
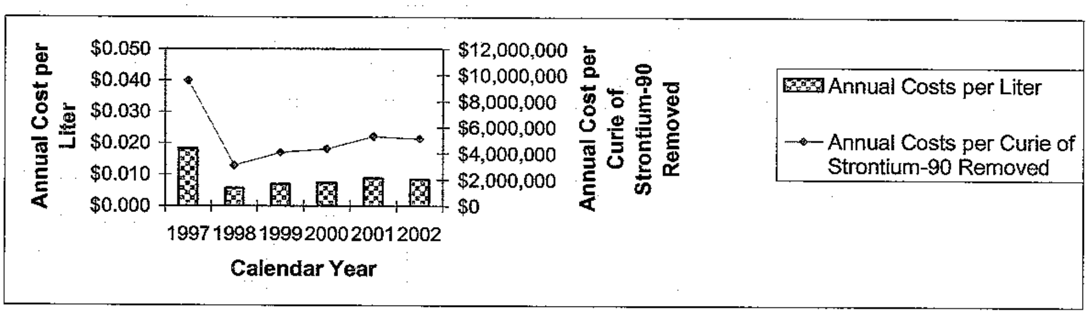


Figure 5-3. Cost Breakdown for 100-NR-2 Pump-and-Treat Construction and Operations.

	Actual Costs X 1000							
Description	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
Design	$ 150.3	$ 2,289.4	$ 951.8	$ 32.6	$ 0.2	$ --	$ --	$ --
Treatment System Capital Construction	$ 8,163.0	$ 55.0	$ --	$ --	$ --	$ --	$ --	$ --
Project Support	$ --	$ --	$ 119.4	$ 136.0	$ 113.1	$ 96.3	$ 183.5	$ 219.4
Operations & Maintenance	$ 245.3	$ 2,622.7	$ 1,027.8	$ 425.2	$ 657.4	$ 462.2	$ 631.5	$ 664.2
Performance Monitoring	$ --	$ --	$ --	$ --	$ --	$ 82.6	$ 83.1	$ 46.6
Waste Management	$ --	$ --	$ --	$ --	$ --	$ 131.6	$ 112.5	$ 93.4
Totals	$ 8,558.6	$ 4,967.1	$ 2,099.0	$ 593.8	$ 770.7	$ 772.7	$* 1,010.6	$ 1,023.6

NOTES:
- = not available.
*= 2001 costs corrected for Project Support. Initial expense calculations were not properly categorized.





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